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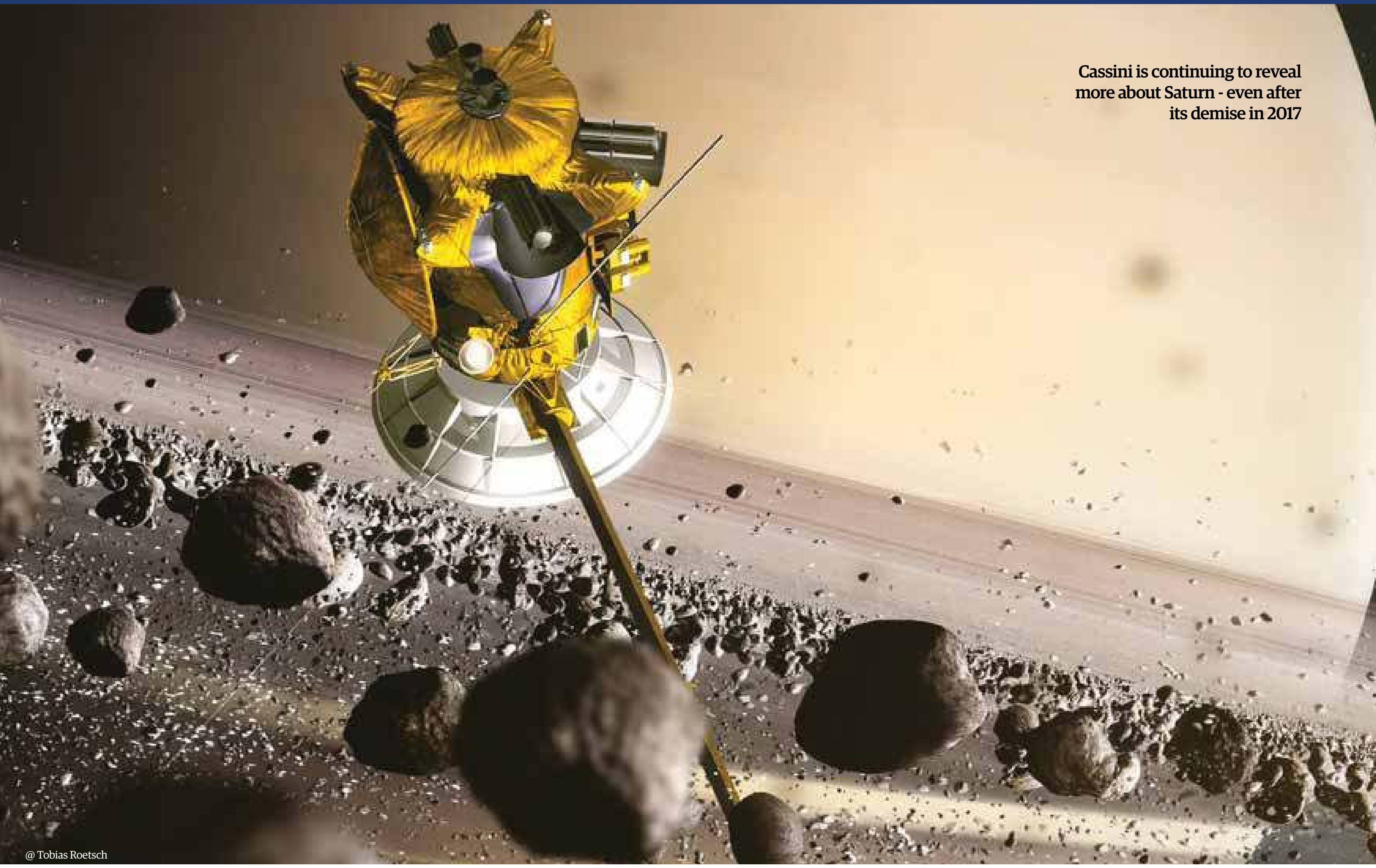

Cassini is continuing to reveal more about Saturn - even after its demise in 2017

@ Tobias Roetsch

# Welcome

Dark energy: it's the mysterious force that's tearing the universe apart. But, as we explore in this issue, we're slowly but surely beginning to crack one of the biggest mysteries of the universe. What is it? How does it determine the fate of the universe? How will the cosmos actually end – will it be a Big Crunch or a Big Rip? Over on page 16 the astrophysicists have the answers – and precisely where we're at in our unravelling of this invisible portion of the cosmos.

Of course, this is the last issue of the year, so it makes sense that we give you a round-up of the events that'll be happening throughout 2019, featuring the best stargazing events, rocket launches and even some brand-new missions on a quest to answer the most pressing questions in the cosmos. With New Horizons finally arriving at 2014 MU69 – or, perhaps the easier to remember, Ultima Thule – on 1 January 2019, we've provided everything you need to know about the very first flyby of a Kuiper Belt Object, in the words of New Horizons' principal investigator Alan Stern.

And that's not all – we've revealed the hottest astronomy products that you need to buy in the New Year – from the latest in astroimaging to the best telescopes (whatever your level of ability) – to make your experiences under the night sky all the more exquisite.

Merry Christmas and a Happy New Year – hope it's a good one!

**Gemma Lavender**
Editor-in-Chief

## Our contributors include...

**Graham Southorn**
*Science writer*
The former editor of *BBC Focus* reveals the latest on what we really know about dark energy: the force tearing space apart.

**Ian Evenden**
*Science writer*
What will New Horizons encounter at Ultima Thule? Ian speaks to the mission's experts who reveal more about life after Pluto – and what we can expect on 1 January.

**Giles Sparrow**
*Space science writer*
Find out the surprising things we discovered from the late Cassini mission – just revealed by scientists at NASA. Giles has the details over on page 56.

**Stuart Atkinson**
*Astronomer*
As we head into the New Year, Stuart reveals the sights that you simply can't miss and the tutorials to hone your observing and imaging skills.



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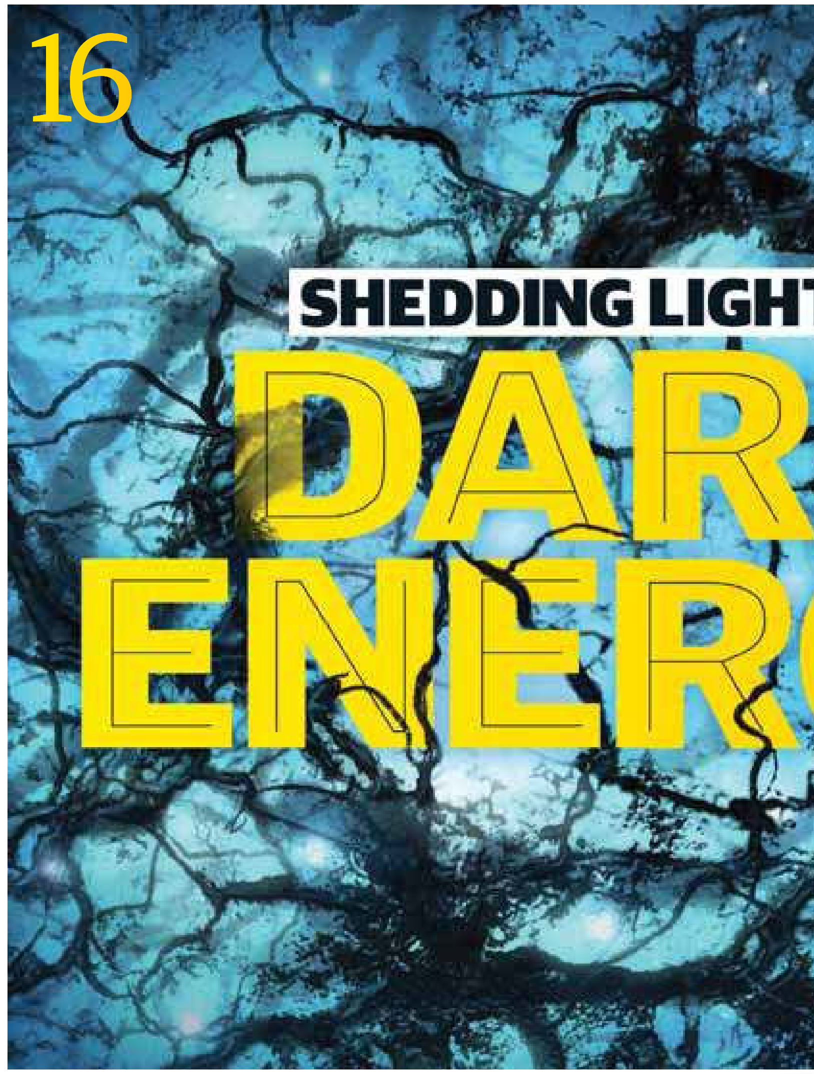


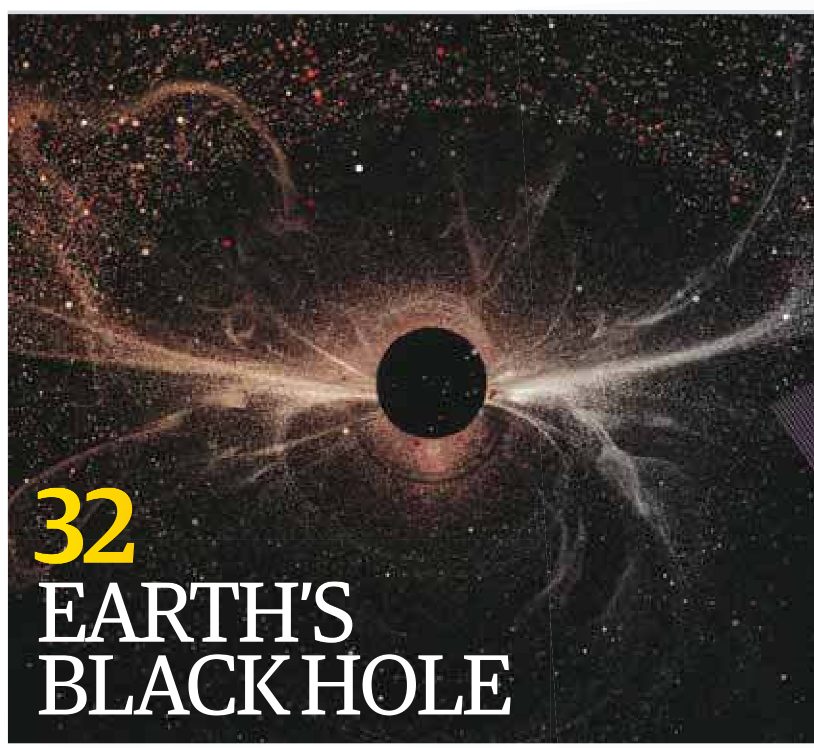

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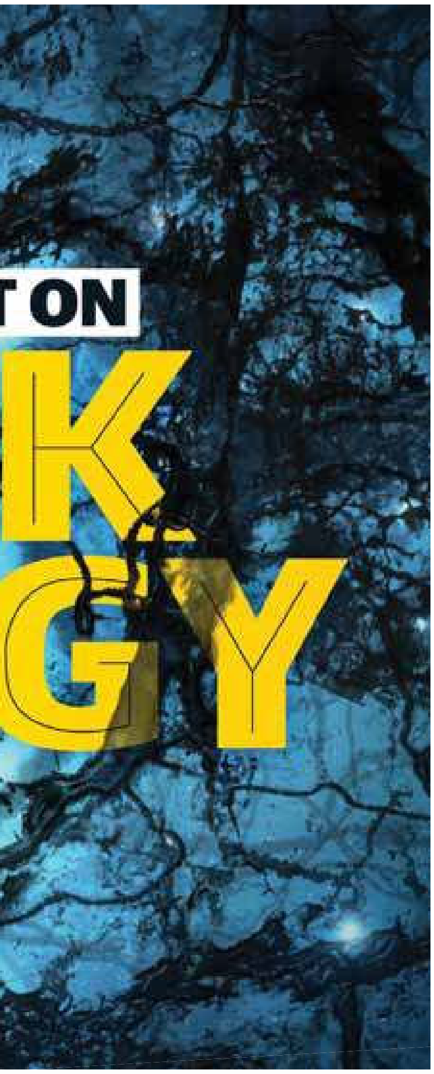



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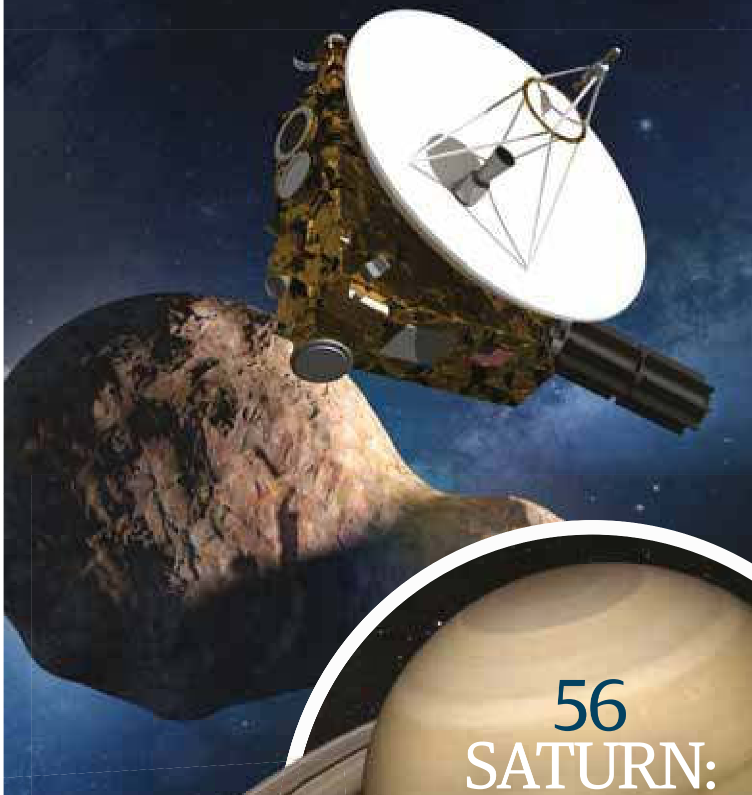


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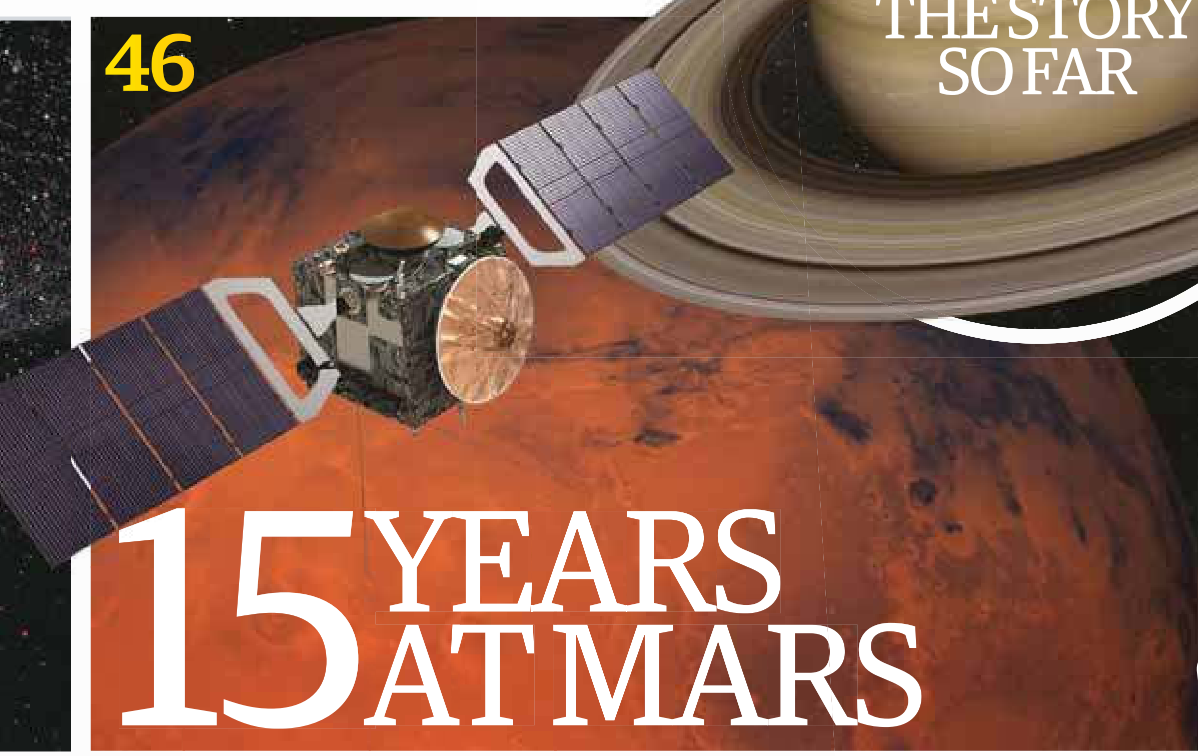

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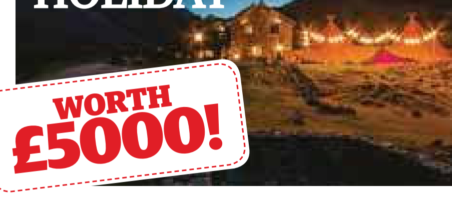

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# LAUNCH PAD
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## A colourful encounter between river and sea

Snapped by Landsat 8, an Earth-observation satellite that's operated by NASA and the United States Geological Survey, here is a stunning scene where the Gulf of Mexico meets with the Suwannee River. This striking image recently won this year's Envisioning Research image competition held by North California State University.

As water flows through the Suwannee River, it collects organic matter that degrades into a tannic substance that provides the dark colour permeating through the green-blue waters of the Gulf of Mexico.

© Alice Alonso/NC State

## Frozen river from space

European Space Agency (ESA) astronaut Thomas Pesquet, who was aboard the International Space Station (ISS) for Expedition 50, captured this marvellous landscape of the 2,250 kilometre (1,400 mile) Dnieper River, which flows to the Black Sea from Russia.

On 9 February 2017, Pesquet captured this unique winter landscape from an altitude of around 320 kilometres (200 miles) as the ISS travelled around the Earth at high speeds, completing 16 orbits of our home planet in just one day.

© NASA/ESA

# Piece of Orion's puzzle

NASA's Orion spacecraft will become a powerhouse for space exploration in the near future. Pictured here, the European-built Service Module can be seen on its way to Kennedy Space Centre in Florida, United States, from Hamburg, Germany.

The European Service Module (ESM) was loaded onto an Antonov An-124 Ruslan aircraft and flown over the Atlantic in preparation for Exploration Mission-1, the first integrated flight test of NASA's Deep Space Exploration Systems. The ESM in this case will propel, power and cool Orion during flight.

© NASA

## Square icebergs, straight ahead

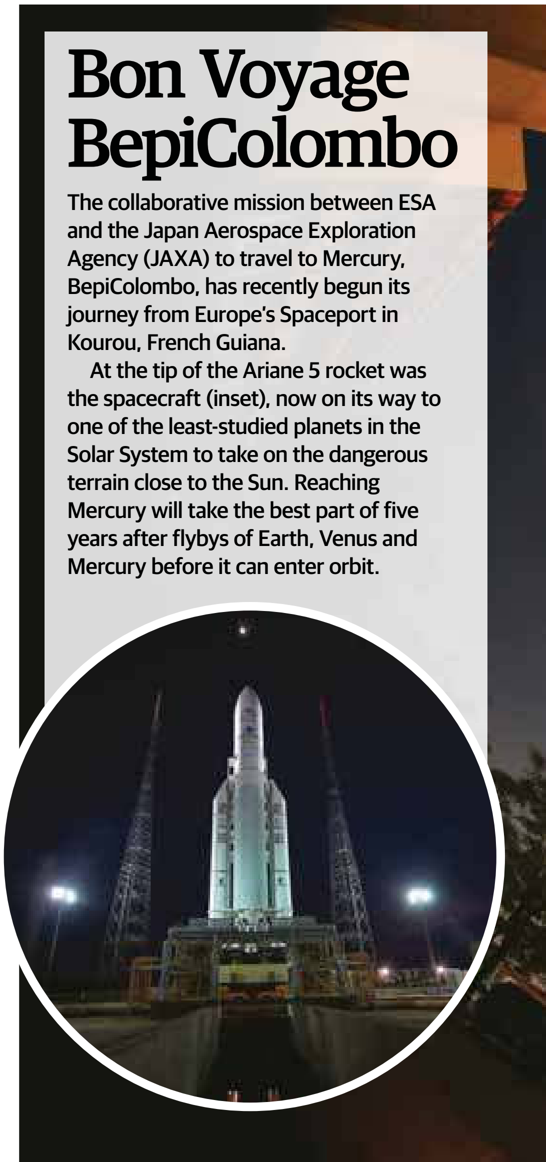
NASA's Operation IceBridge undergoes airborne surveys of the Earth's polar ice. In this image, scientists got the chance to investigate the northern Antarctic Peninsula on 16 October 2018 and spotted these unusually rectangular icebergs.

This strange icy platform was captured by IceBridge senior support scientist Jeremy Harbeck who was particularly interested in the A68 iceberg, which is the size of the state of Delaware. Harbeck was surprised as he had "never seen an iceberg with two corners at such right angles."

© NASA/ESA

## Cosmic trick or treat

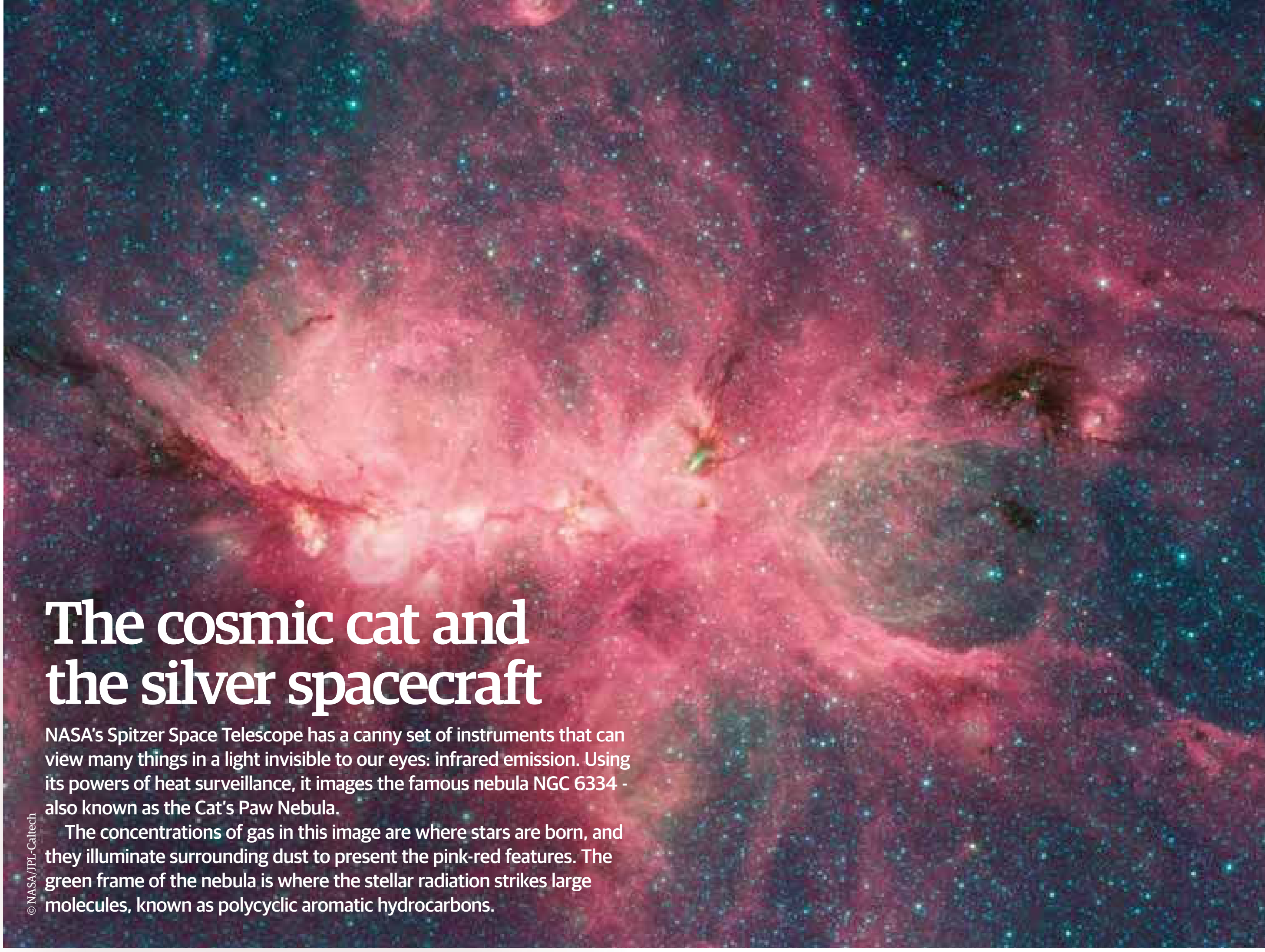
Everyone was given a treat in this case as NASA and ESA's Hubble Space Telescope photographed a cosmic bat for Halloween. In the Serpens Nebula, nearly 1,300 light years from Earth, the Sun-like star HBC 672 has moulded an encompassing ring of debris, the shadow of which was spotted by Hubble – seen in the upper right of the image. This feature has been nicknamed the 'Bat Shadow' and is roughly 200-times longer than the Solar System.



## Bon Voyage BepiColombo

The collaborative mission between ESA and the Japan Aerospace Exploration Agency (JAXA) to travel to Mercury, BepiColombo, has recently begun its journey from Europe's Spaceport in Kourou, French Guiana.

At the tip of the Ariane 5 rocket was the spacecraft (inset), now on its way to one of the least-studied planets in the Solar System to take on the dangerous terrain close to the Sun. Reaching Mercury will take the best part of five years after flybys of Earth, Venus and Mercury before it can enter orbit.



# The cosmic cat and the silver spacecraft

NASA's Spitzer Space Telescope has a canny set of instruments that can view many things in a light invisible to our eyes: infrared emission. Using its powers of heat surveillance, it images the famous nebula NGC 6334 - also known as the Cat's Paw Nebula.

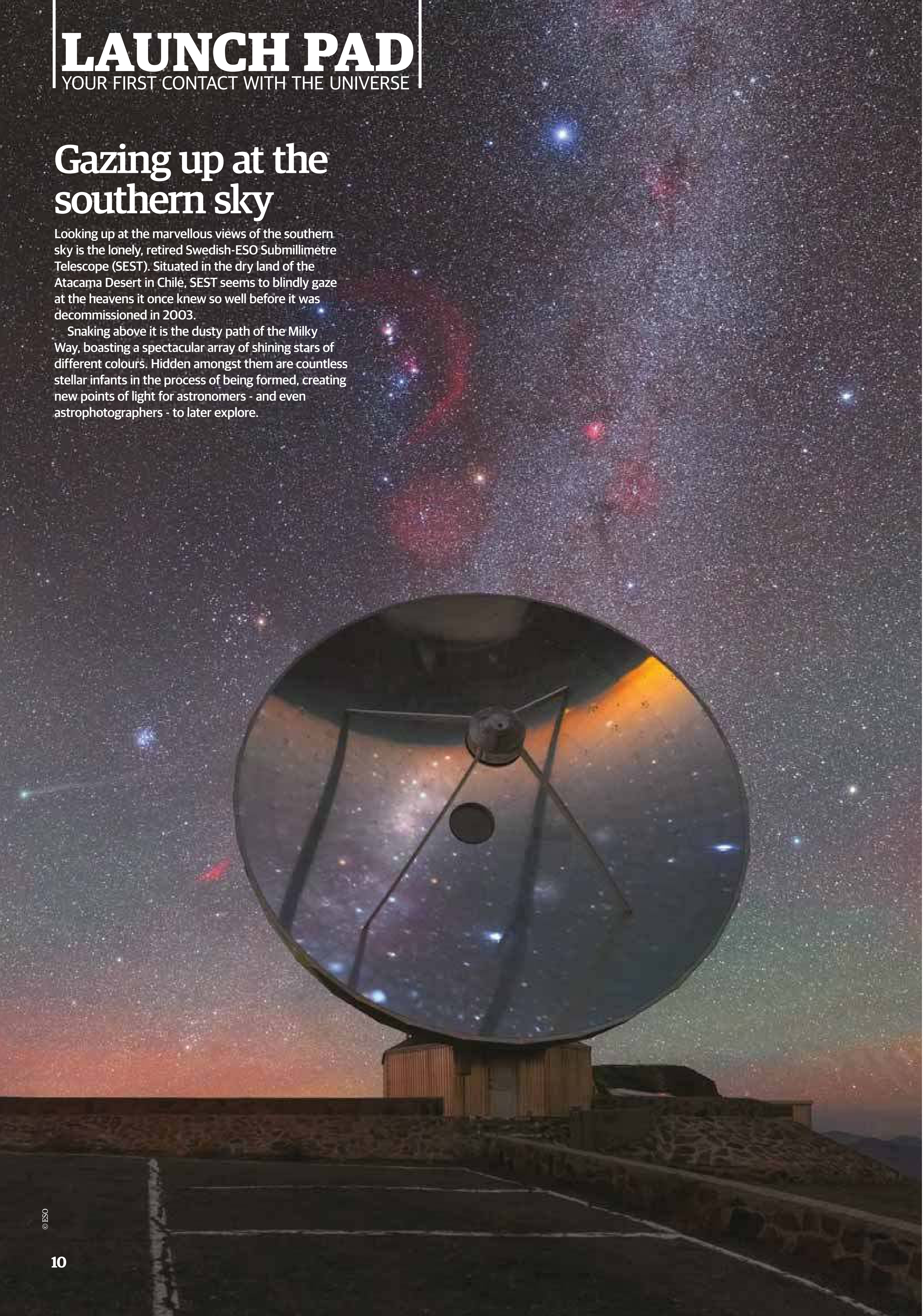
The concentrations of gas in this image are where stars are born, and they illuminate surrounding dust to present the pink-red features. The green frame of the nebula is where the stellar radiation strikes large molecules, known as polycyclic aromatic hydrocarbons.



# Gazing up at the southern sky

Looking up at the marvellous views of the southern sky is the lonely, retired Swedish-ESO Submillimetre Telescope (SEST). Situated in the dry land of the Atacama Desert in Chile, SEST seems to blindly gaze at the heavens it once knew so well before it was decommissioned in 2003.

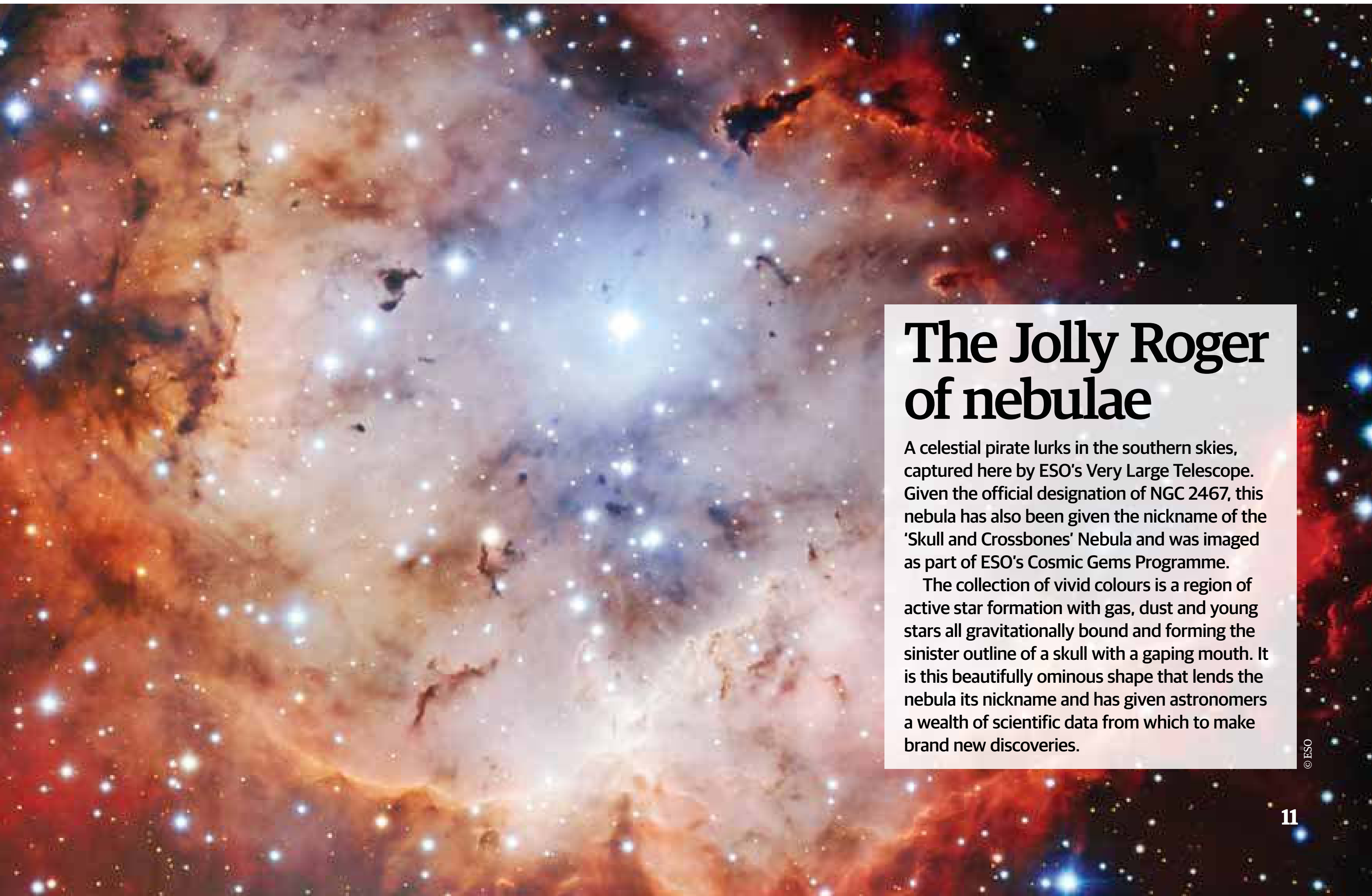
Snaking above it is the dusty path of the Milky Way, boasting a spectacular array of shining stars of different colours. Hidden amongst them are countless stellar infants in the process of being formed, creating new points of light for astronomers - and even astrophotographers - to later explore.



# Uncovering ancient superclusters

Astronomers utilised the powerful light-collecting abilities of the European Southern Observatory's (ESO) Very Large Telescope to find a behemoth cosmic structure that was formed just two billion years after the Big Bang. This proto-supercluster of galaxies has been nicknamed Hyperion and, at an estimated mass of more than one million billion-times that of our Sun, is the 'heaviest' and largest structure to be found at such an incredible distance of 11 billion light years away, dating it at roughly 20 per cent the universe's current age.





# The Jolly Roger of nebulae

A celestial pirate lurks in the southern skies, captured here by ESO's Very Large Telescope. Given the official designation of NGC 2467, this nebula has also been given the nickname of the 'Skull and Crossbones' Nebula and was imaged as part of ESO's Cosmic Gems Programme.

The collection of vivid colours is a region of active star formation with gas, dust and young stars all gravitationally bound and forming the sinister outline of a skull with a gaping mouth. It is this beautifully ominous shape that lends the nebula its nickname and has given astronomers a wealth of scientific data from which to make brand new discoveries.

# Early Earth was 'most likely' purple

## A molecule which appeared before chlorophyll may have given organisms a rather unusual appearance

Researchers funded by NASA are suggesting that our planet was once distinctly purple. Scientists say early life forms on Earth used a molecule called retinal to absorb the Sun's rays. Since retinal's pigments absorbed green and yellow light while transmitting red and blue, a purple Earth is believed to have been the result.

The conclusion is based on the way that chlorophyll makes use of lower wavelength red and blue light rather than green, which is particularly rich in energy. Shiladitya DasSarma, professor of molecular biology at the University of Maryland, and her co-author Dr Edward Schwieterman, an astrobiologist at the University of California, worked on the hunch that something else must have been absorbing green light and devised a hypothesis involving retinal.

The idea is that retinal and chlorophyll evolved in tandem. Chlorophyll simply absorbed the wavelengths that retinal did not, but the visual effect would have been stark. Indeed, DasSama says it would have "profoundly impacted the development of photosynthesis". This would have happened 2.4 to 3.5 billion years ago, before the Great Oxygenation Event which introduced free oxygen into our atmosphere – an event understood to have been sparked by cyanobacteria, which can perform photosynthesis via chlorophyll.

The conclusions have wide-ranging repercussions in the ongoing search for life, meaning scientists should be keeping an eye out for purple organisms as well as green. "Retinal photopigments may serve as remote biosignatures for exoplanet research," says DasSarma. This works on the assumption that what has taken place on Earth will likely occur on other planets harbouring life.

"The conclusions have some wide-ranging repercussions in the ongoing search for life"

We're used to seeing Earth as a mass of green and desert brown, but the planet may have once appeared purple

# Exoplanet hunter heralds a new era in the search for worlds

## Deputy director of TESS says much has been learned from Kepler, ensuring discoveries will come quickly

The deputy director of a NASA mission that is currently hunting for new planets has heaped praise on the legacy of the much-acclaimed Kepler mission. Massachusetts Institute of Technology (MIT) astronomer Sara Seager says Kepler – which officially came to an end on 30 October – opened scientific eyes to the unexpected, ensuring researchers are better equipped to process the data currently being sent home by the Transiting Exoplanet Survey Satellite (TESS).

TESS, which launched back in April, is expected to identify as many as 2,000 to 3,000 new planets over its initial two years of operation by looking for dips in brightness as orbiting worlds pass by. "Finding planets with the transit method has just become quite standard," she explains, pointing to the method used by Kepler. "TESS didn't have to solve those [extremely] big problems."

An artist's impression of how TESS looks as it surveys 200,000 of the brightest stars near the Sun for transiting exoplanets

Indeed, with four camera-detectors as part of its high-tech repertoire, Seager is convinced TESS will herald a new era for discovery, particularly as it will cover an area 400-times larger than that of Kepler, taking in some 200,000 nearby stars. Already two possible planets have been identified since TESS began science observations in June, and many more are expected, with Kepler having already taught scientists that Earth-sized planets are practically everywhere.

"Kepler was a game-changer; it was so pioneering for exoplanets," Seager says, adding that Kepler discovered planets two- or three-times the size of Earth were ten-times more common than planets like Jupiter. Kepler also gathered data that suggested some planets orbited stars in less than a terrestrial day or were so hot their surfaces are liquid lava. "Before Kepler launched we only knew of hundreds of exoplanets," Seager says "And Kepler found thousands of them."

# Harvard: Asteroid could be alien spacecraft

## Scientists suggest 'Oumuamua could have been a space probe sent by an advanced civilisation

An odd interstellar object which flew through our Solar System - before speeding up and departing - may well have been an alien spacecraft. At least that's according to new research by Harvard scientists which says we cannot rule out that an advanced alien civilisation sent it as a probe.

Ever since 'Oumuamua flew past Earth in October 2017, scientists have pondered what it could have been. They were intrigued by its strange, quickly spinning behaviour and its noted acceleration, with researchers Shmuel Bialy and Abraham Loeb now suggesting it could have been a 'light sail' using the Sun for energy.

It's certainly a more outlandish classification given it was originally regarded as a comet or an asteroid. But Bialy and Loeb say the lack of a tail or coma is likely to rule that out. By contrast, if it was a light sail "floating in interstellar space as debris from an advanced technology equipment", they reckon it could survive for as many as 16,000 light years.

Should it ever be proven true it would quite obviously be a major breakthrough and a huge world event. Of course it would also lead to many follow-up questions, notably why was it here and was it sent our way on purpose?

An artist's impression of the cigar-shaped asteroid 'Oumuamua

© ESO

An artist's impression of the Parker Solar Probe – named after physicist Eugene Parker – getting close to the Sun

# Spacecraft makes the closest-ever solar approach

## The probe was exposed to intense heat and solar radiation in a complex solar wind environment, NASA says

NASA's Parker Solar Probe has managed to survive a trip which took it closer to the Sun than any spacecraft before it. The vessel got within 24 million kilometres (15 million miles) of the surface of our star while enduring temperatures of some 2 million degrees Celsius (3.6 million degrees Fahrenheit) before indicating to controllers back on Earth that it was safe and still functioning.

It's the first time a spacecraft has penetrated the outer atmosphere of the Sun, and it did so at 343,273 kilometres (213,200 miles) per hour at its closest approach – setting a speed record in the process. Scientists are hoping to get the spacecraft even closer: by 2025 it will get within 6.1 million kilometres (3.83 million miles) of the Sun's surface when it will accelerate to a speedy 692,017 kilometres (430,000 miles) per hour thanks to the Sun's gravity.

Before then the probe will make 23 further approaches, with the next due to take place in April. It is hoped the spacecraft will teach us much about the structure of the Sun, its composition and activity, while also shedding light on why the corona is much hotter than the surface.

"These observations, gathered closer to the Sun than ever before, will help scientists begin to answer outstanding questions about the Sun's fundamental physics," NASA says. The previous closest encounter with the Sun was made by Helios 2 in 1976, which got to within 42.8 million kilometres (26.6 million miles) of the surface.

# Billionaire to fund a bold search for life

## Yuri Milner is set to fund a private mission to Saturn's sixth-largest moon, Enceladus

A privately funded mission to seek faraway alien life looks increasingly likely to get off the ground thanks to backing from a billionaire investor. Breakthrough Initiatives' founder, the Russian-Israeli Yuri Milner, believes private backing for a mission would allow for greater risk taking, and he appears undeterred by costs that could exceed $100 million.

Breakthrough Initiatives has already spent huge amounts of money in its search for intelligent creatures outside of Earth and it is also looking into developing a small, laser-sailing spacecraft named StarChip that can travel 4.37 light years away to the Alpha Centauri star system.

Milner believes a new mission – which he says will be backed by NASA – could target Venus, Jupiter's satellite Europa or, most likely, Saturn's moon Enceladus. In fact, agreements with NASA appear to have been drafted up for a mission to Enceladus which is likely to have life in the guise of microbes within volcanic vents on the ocean floor. The American space agency would offer scientific, technic and financial assistance, with $70,000 already earmarked for a concept study of a flyby mission.

Milner, who also says the clouds above Venus could harbour life, was talking at the Breakthrough Prize ceremony held at NASA's Ames Search Center in November, which handed out seven awards of $3 million to projects showing significant scientific advances in life sciences, fundamental physics and mathematics. He has ruled out Mars for the time being saying: "Most of the experts agree that if you find something, it will most likely be some historical artefacts of life, rather than a living organism," he says. "But you never know."

NASA is understood to be supporting Breakthrough Initiatives' plan for a privately funded Enceladus mission

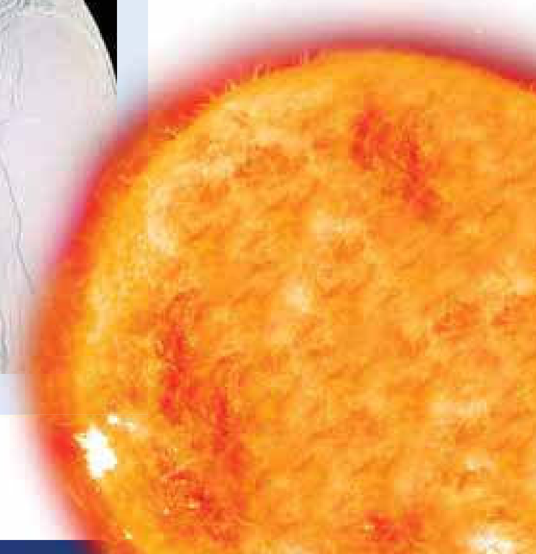
# Earth's water likely came from the Sun

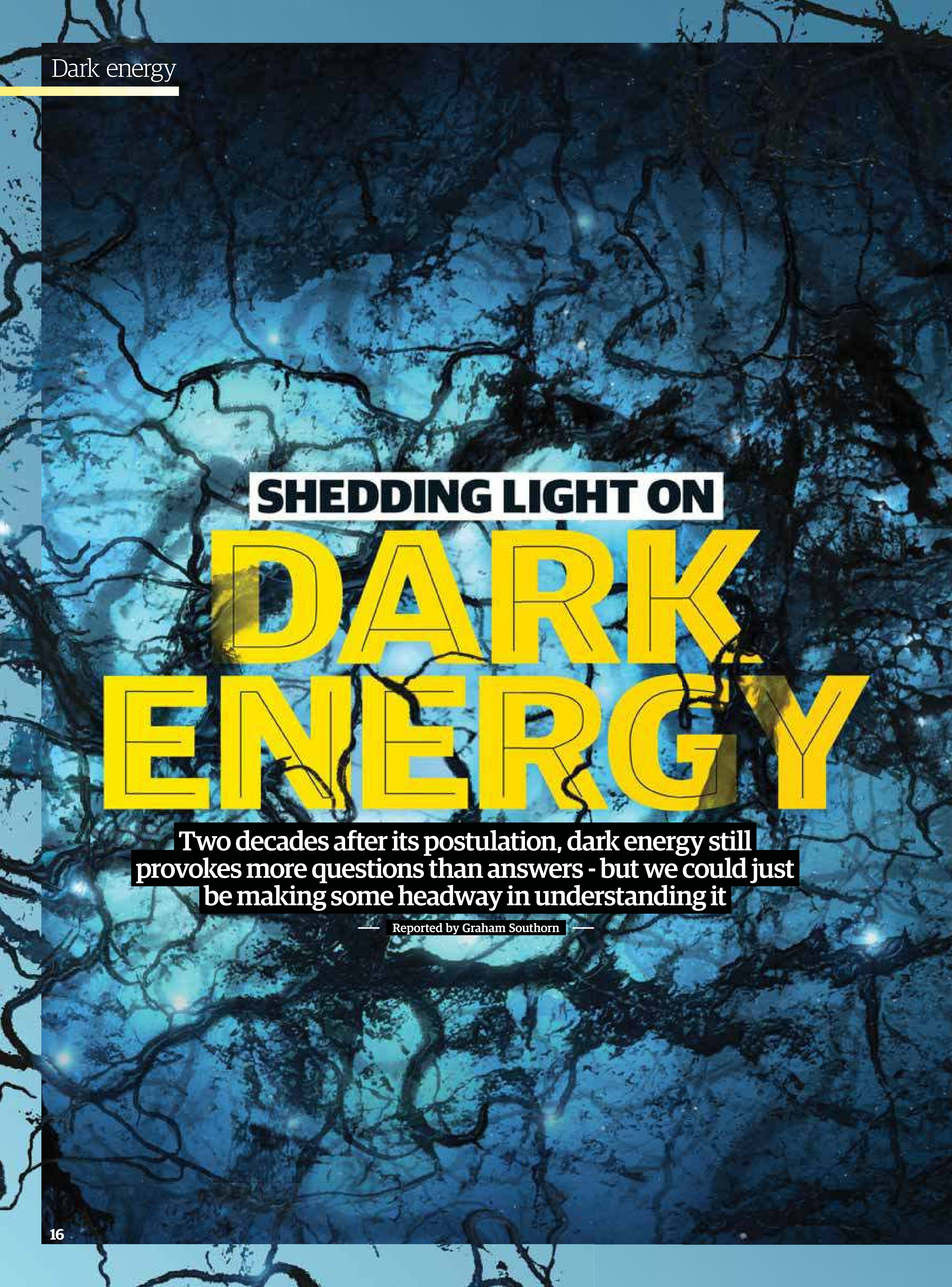
## It's thought to have partially formed from the solar nebula as well as from water-laden asteroids

Scientists from Arizona State University say Earth's water may have been formed in some small part by the swirling material and gas that was left over from the Sun's formation. According to academic researchers led by Jun Wu, most of Earth's hydrogen was carried by asteroids billions of years ago, but around one per cent of the water molecules on our planet came from the solar nebula as Earth siphoned dust and gas during its newborn, still-molten phase.

They came to their conclusion after studying the ratio of hydrogen and a heavier isotope called deuterium, discovering that in the region where the mantle meets the core there was noticeably more hydrogen than deuterium when compared with ocean water. They say this points to a non-asteroid source, with nebular hydrogen dissolving into the molten iron of the magma ocean.

"This model suggests that the inevitable formation of water would likely occur on any sufficiently large rocky exoplanets in extrasolar systems," Wu says, suggesting that Earth-like planets that haven't had access to water-loaded asteroids could still obtain water from their system's own solar nebula. "I think this is very exciting."





# SHEDDING LIGHT ON DARK ENERGY

**Two decades after its postulation, dark energy still provokes more questions than answers - but we could just be making some headway in understanding it**

— Reported by Graham Southorn —

Two decades ago, astronomers studying distant stars made a dramatic discovery. They were investigating the future of the universe, which was known to be expanding. Contrary to all expectations they discovered that the rate of expansion was actually speeding up – the universe was getting bigger, and faster. Today the focus is on finding the cause of this unexplained phenomenon, which has been given a suitably mysterious moniker: 'dark energy'.

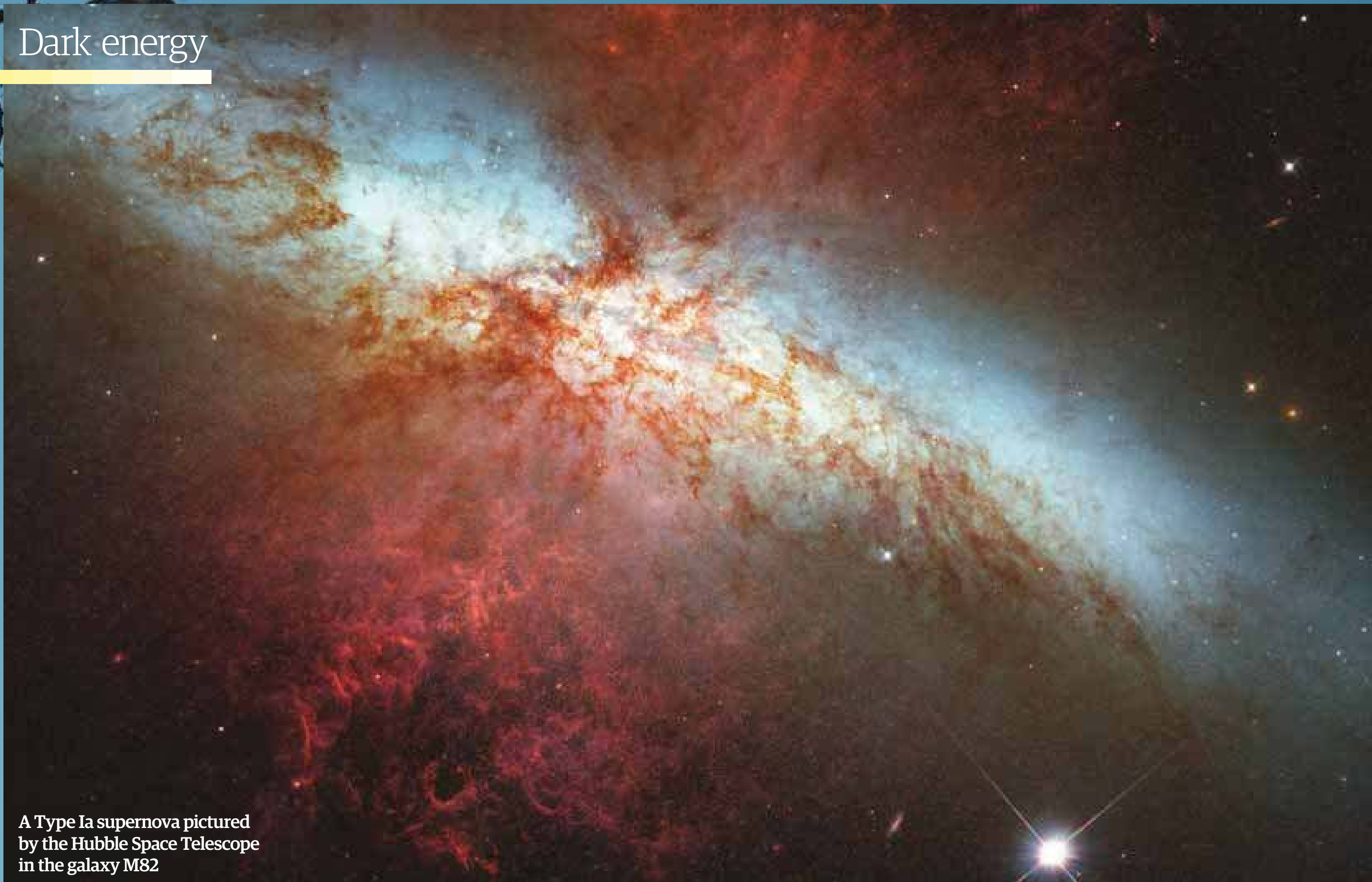
The discovery that the universe was expanding ever faster came as a huge surprise. In fact, it was so significant that it led to the award of a Physics Nobel prize in 2011 to Saul Perlmutter, Brian P Schmidt and Adam G Riess.

These were the leading scientists from two competing teams who studied light from a particular type of exploding star – and lots of them. Type Ia supernovae flare up in a predictable way, so their relative brightness reveals how far away they are. Their redshifts – the elongation of wavelengths towards the red end of the spectrum – showed that it was those furthest away that were receding the fastest.

It was the opposite to what most scientists expected, says Robert Crittenden, professor of cosmology at the University of Portsmouth. "We'd always assumed that because gravity was attractive, the rate of expansion would be slowing down. Distant galaxies would be gravitationally attracted to each other and that would be slowing down the expansion of the universe," he says.

The discovery that the universe was expanding faster than before begged a question: what was causing it? The simplest solution, which many scientists still believe will ultimately prove to be the correct one, is decades old. It comes from Albert Einstein's general theory of relativity, which describes how gravity operates.

Before he published it in 1917, Einstein wrestled with one of its predictions. He believed that the universe was static, and yet the general theory of relativity predicted it would either expand or contract. In order to keep things in balance, he added a term to the equations: the famous cosmological constant.



A Type Ia supernova pictured by the Hubble Space Telescope in the galaxy M82

It was effectively a fudge, and it wouldn't last long. By the 1930s Edwin Hubble's observations of distant galaxies had shown that the universe wasn't static at all, but was expanding, and so Einstein abandoned the cosmological constant, reportedly calling it his "biggest blunder".

In the 21st century, though, the cosmological constant is back as the leading explanation for dark energy. In physical terms it's a number that describes the energy density of empty space. Even a perfect vacuum, devoid of any particles, is not devoid of energy. As the universe expands and more space is created, there's more energy to push things outward.

This isn't hypothetical. There's a physical mechanism that explains where the energy comes from which can be found in another branch of physics: quantum mechanics. It says that temporary particles pop in and out of existence – a phenomenon that's been observed in particle experiments on Earth.

There's just one very big problem. Quantum calculations have produced a number for the energy density of empty space, but it's way, way bigger than what's required. "The cosmological constant is a very simple model, but when you try to relate it to fundamental physics the value you get is arguably 100 orders of magnitude different from what you expect. Apart from that it works very well in explaining what we see, but because of that problem people look at other ways to solve the riddle," says Crittenden.

One of the other ways of explaining dark energy is an energy field that isn't constant. Rather, it's dynamic. Its value changes over space and time, driving the expansion of the universe differently now compared to how it did in the past. The universe may have been born a long time ago – 13.8 billion years ago at the Big Bang – but dark energy has only come to dominate the expansion for the past 5 billion years or so.

There are many variations of this idea, which goes by the name of quintessence, or 'fifth force'. In physics terminology it would be a 'scalar field', similar to the Higgs field. And just as the Higgs field has an associated particle – the Higgs boson – so would the scalar field be responsible for dark energy.

A particle that could be responsible for dark energy has never been detected, but strangely enough this non-detection works in its favour as an explanation. Out in the far-flung reaches of the universe the field would be strong enough to fling galaxies apart, but in the presence of other masses around it, like in laboratories on Earth, the force it exerts would be miniscule.

One such hypothetical particle is called the chameleon. It can change its mass depending on the density of its surroundings, explains Clare Burrage, associate professor at the University of Nottingham. "Chameleons can self-camouflage.

The Victor M Blanco telescope in Chile captures light for the Dark Energy Survey

They can learn about their environment and adjust their properties so that the modification of gravity is hidden from experiments. But they can't hide from everything, so if you do a suitably chosen experiment you might be able to see its effects. We're using a technique called atom interferometry that's really sensitive to these forces."

The chameleon force would be exerted solely by the outer shell of an object rather than, say, gravity on Earth, which is exerted by the entire planet. This idea explains why the force would be so weak and why the experiments, which involve detecting the motion of atoms in free fall, needs to be super-sensitive.

"One of the interesting things about these theories is that you can design an experiment on Earth that might make their effects show up. It doesn't need to be in a huge particle collider. You just need to do the right kind of really sensitive measurement, using equipment that could fit on a couple of table tops. It's done on a small scale on a reasonably short timescale – a very different way of studying dark energy than launching a telescope, which can take decades," says Burrage.

The University of Nottingham team has yet to publish its results, and a group using the same technique at the University of California, Berkeley, has yet to spot anything unusual.

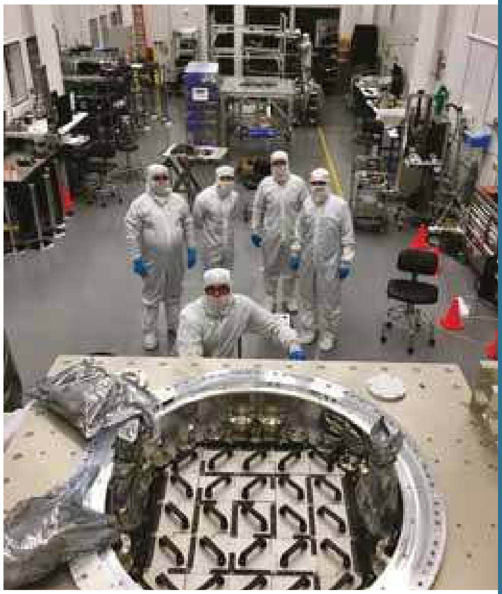
While physicists look for tell-tale signs in the lab, many astronomers have focused on making more precise maps of how the universe has evolved over time. One kind of map that's particularly important reveals the location of not just ordinary matter, of the kind that constitutes stars and planets, but dark matter too.

Dark matter is another cosmic mystery all by itself – an invisible form of matter that, like dark energy, has evaded detection. But while the particles making up dark matter have yet to be identified, its effects are clearly visible. Crittenden explains: "We've known about dark matter for a while longer than dark energy, and we need it on a smaller scale than the universe [as a whole]. Visible matter isn't nearly enough to explain the dynamics of stars around galaxies and galaxies around clusters of galaxies – we need a significant amount of dark matter as well."

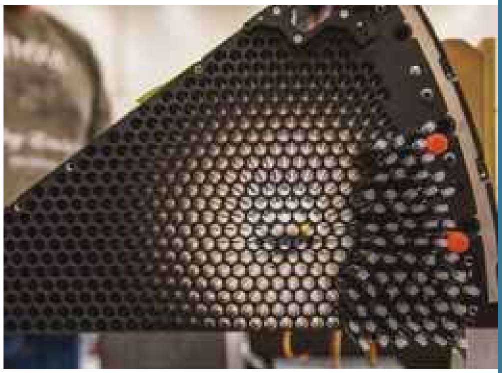
The currently accepted model of the universe holds that it's geometrically flat. And if this is so then dark matter must account for a staggering 27 per cent of all its mass-energy. Ordinary matter would make up just 5 per cent and the remaining 68 per cent would be dark energy.

However, dark matter and dark energy don't behave in the same way, says Crittenden. "Dark matter is generally attractive – it's like ordinary matter in how it gravitates. Dark energy has a very different effect – it doesn't cluster galaxies together and it's difficult to see its effect on individual galaxies."

Whereas dark matter acts to pull galaxies together, dark energy tries to pull them apart. This



Cooling device for the world's largest digital camera – part of the Large Synoptic Survey Telescope



The fibres of the DESI can capture 5,000 galaxies simultaneously

"Visible matter isn't nearly enough to explain the dynamics of galaxies around clusters of galaxies" **Prof Robert Crittenden**

## What is dark energy?

What do scientists think the mysterious phenomenon is?

If you pressed me I'd go for the accelerated expansion of the universe being driven by a new kind of scalar field.

**Prof Catherine Heymans, University of Edinburgh**

If forced to bet I'd go for the cosmological constant – I think you'd get low odds for anything else!

**Dr Thomas Kitching, Mullard Space Science Laboratory, UCL**

Nothing works perfectly so far. My bet would be that we haven't thought of what will prove to be the right answer.

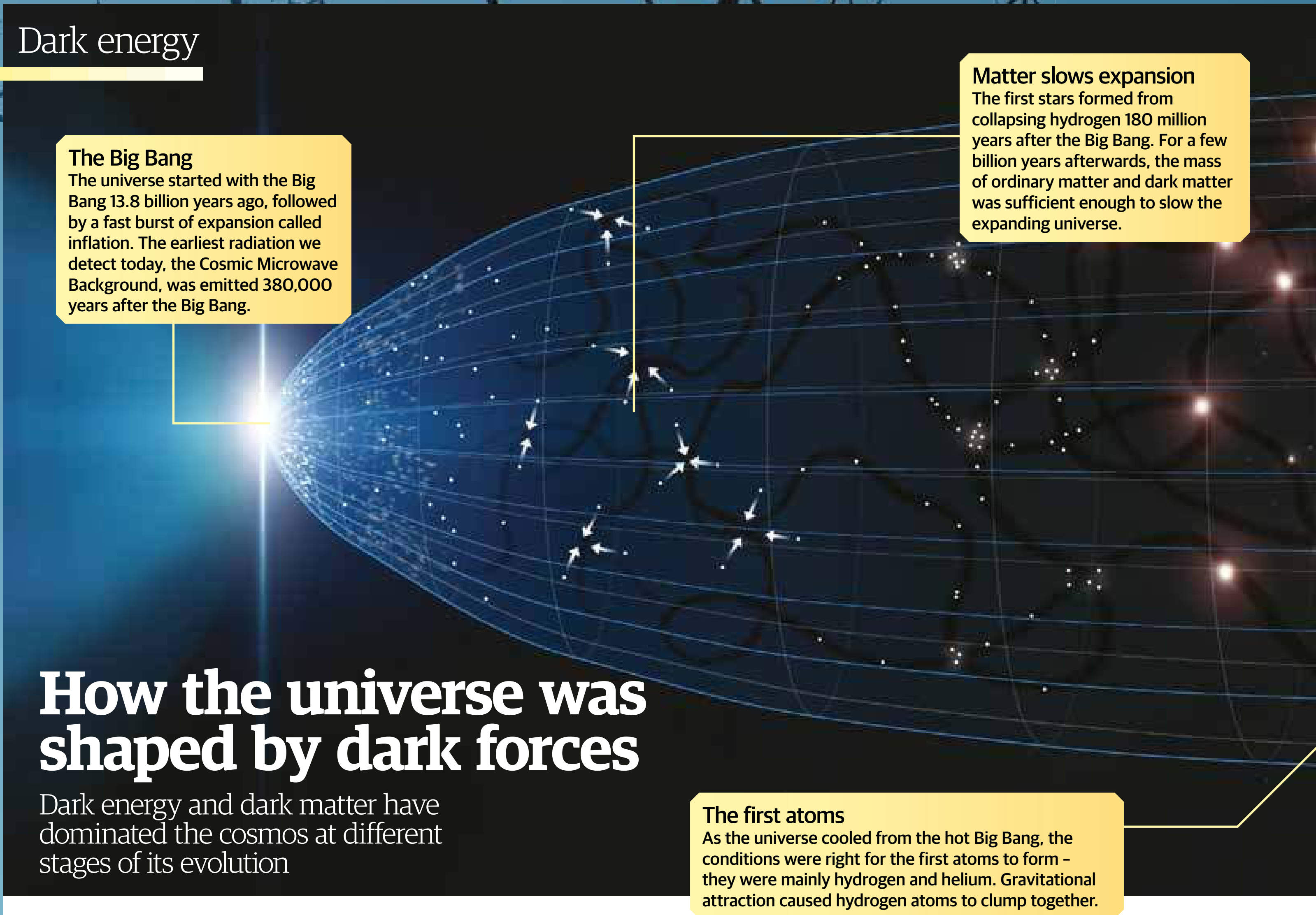
**Dr Clare Burrage, University of Nottingham**

What we see is consistent with the cosmological constant, with the big caveat of its magnitude.

**Prof Robert Crittenden, University of Portsmouth**

# How the universe was shaped by dark forces

Dark energy and dark matter have dominated the cosmos at different stages of its evolution




is where dark matter comes into play in the search for dark energy. By looking at what happens to large structures like clusters of galaxies over time, astronomers hope to learn how dark energy has influenced the evolution of the universe. "It's harder for structures to collapse when the background is expanding or accelerating because dark energy slows down the collapse, and that's the signature we're looking for," explains Crittenden.

So how are these maps made? One method is to look at how clumps of mass distort light as it passes by, a technique called gravitational lensing. An upcoming space telescope called Euclid will use the technique to find dark matter, explains Thomas Kitching, an associate professor at University College London's Mullard Space Science Laboratory and a manager in the Euclid project.

"As light from a galaxy passes through dark matter it gets distorted and bent. If you measure the change in shape you can determine how much dark matter is there, and you can use that to make a dark-matter map of the universe. You can then see how it's evolved over time. The way dark matter has evolved over time depends on what dark energy is," he explains.

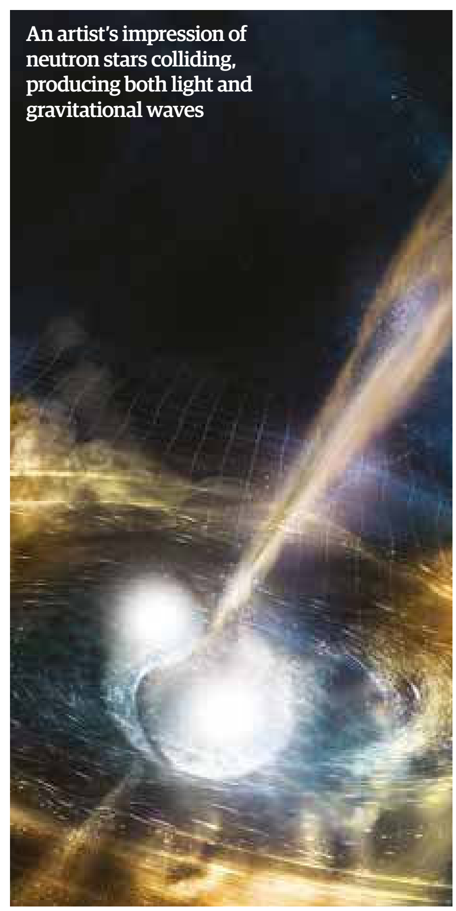
The lensing technique has also been used by astronomers involved in a collaboration called the Kilo-Degree Survey (KiDS), which has used images of the southern sky taken by the Very Large Telscope (VLT) in Chile.

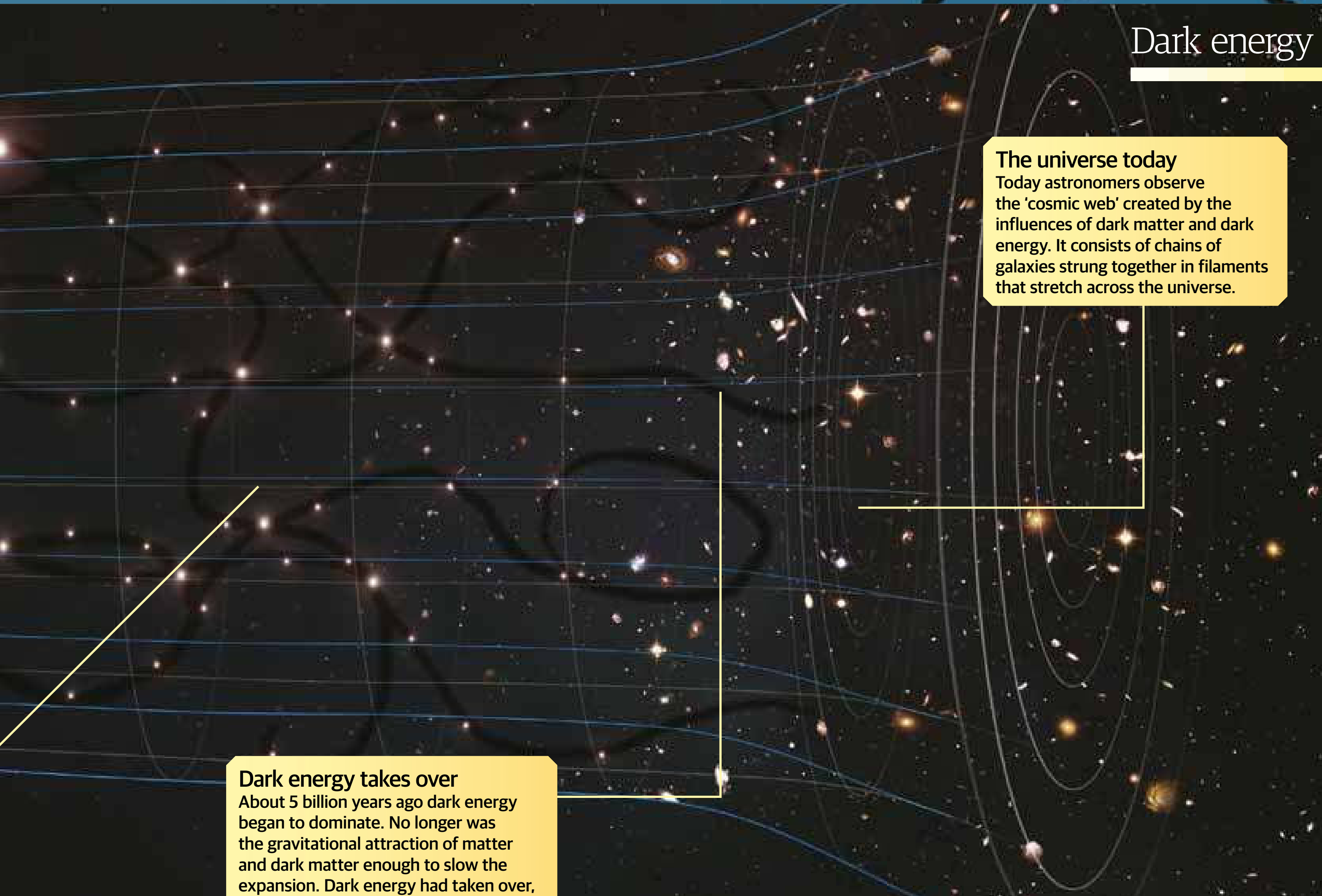
At the University of Edinburgh, Ben Giblin is involved in the KiDS collaboration: "We've measured the amount of matter in the universe and the structure of this matter, and therefore we've indirectly measured dark energy. We've made one measurement, but other people have been observing a very different source – Cosmic Microwave Background (CMB) radiation, which is energy left over from the very early universe. We've come to slightly different conclusions. It's not like we completely disagree, but it's enough of a disagreement to make you scratch your head," he says.

"There's also a disagreement between the scientists who work on CMB and those who study the expansion of the universe with supernovae," he continues. "This maybe adds a little more fuel to the fire that, because we disagree and we're all using the same theory of gravity that involves the cosmological constant, maybe the whole theory of gravity is wrong. But there's not strong enough evidence for that at this point."

The way out of this impasse is to gather more data, and there's certainly more on the way. The Dark Energy Survey, an international collaboration in which the University of Portsmouth is involved, is coming to the end of its five-year mission and is set to release more data. In addition, a new detector, the Dark Energy Spectroscopic Instrument (DESI), will begin examining redshifts to determine the collapse rate of large structures in 2019.

Beyond that, a giant new instrument called the Large Synoptic Survey Telescope will produce the most detailed wide-field survey to date using

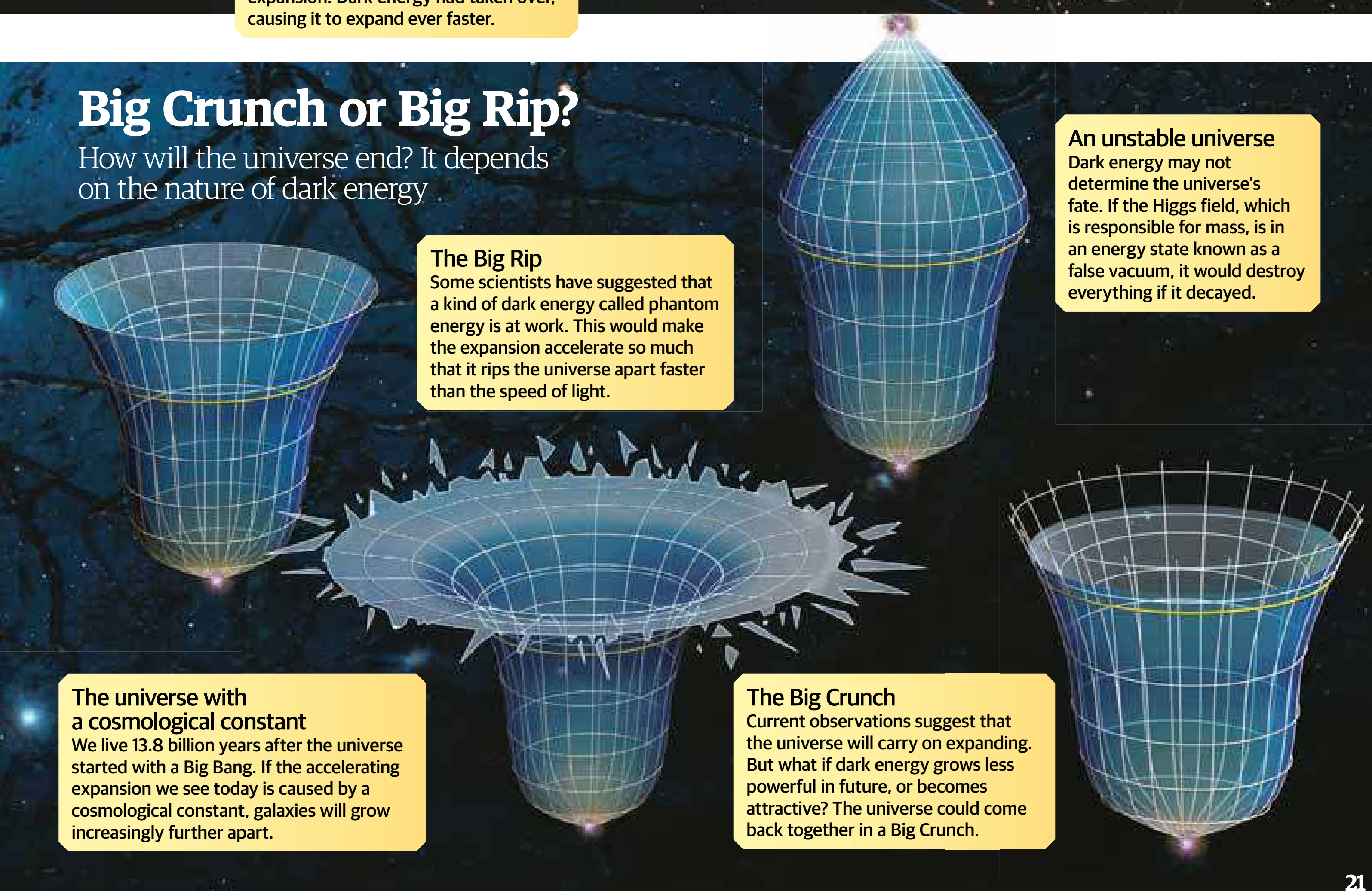

An artist's impression of neutron stars colliding, producing both light and gravitational waves



### The universe today
Today astronomers observe the 'cosmic web' created by the influences of dark matter and dark energy. It consists of chains of galaxies strung together in filaments that stretch across the universe.

### Dark energy takes over
About 5 billion years ago dark energy began to dominate. No longer was the gravitational attraction of matter and dark matter enough to slow the expansion. Dark energy had taken over, causing it to expand ever faster.

## Big Crunch or Big Rip?
How will the universe end? It depends on the nature of dark energy



### The Big Rip
Some scientists have suggested that a kind of dark energy called phantom energy is at work. This would make the expansion accelerate so much that it rips the universe apart faster than the speed of light.

### An unstable universe
Dark energy may not determine the universe's fate. If the Higgs field, which is responsible for mass, is in an energy state known as a false vacuum, it would destroy everything if it decayed.

### The universe with a cosmological constant
We live 13.8 billion years after the universe started with a Big Bang. If the accelerating expansion we see today is caused by a cosmological constant, galaxies will grow increasingly further apart.

### The Big Crunch
Current observations suggest that the universe will carry on expanding. But what if dark energy grows less powerful in future, or becomes attractive? The universe could come back together in a Big Crunch.

# Euclid: mapping the dark universe

The spacecraft's instruments will observe billions of faint galaxies to reveal the signature of dark energy

### Sunshield
The sunshield protects the payload module, which contains the instruments, from the Sun, and supports the solar panels on the other side.

### Solar array
The solar array consists of three panels which together supply up to 2,430 watts of electricity depending on the spacecraft's orientation to the Sun.

### Visible imager (inside)
VIS will take high-quality images equivalent in resolution to those captured by the Hubble Space Telescope. It's designed to measure the shapes of galaxies.

### Telescope
The telescope has three mirrors. Its primary mirror is 1.2 metres (4 foot) in diameter and made of silicon carbide with a silver coating.

### Near-Infrared Spectrometer and Photometer (inside)
The NISP instrument's photometric measurements will be in the near-infrared to obtain the redshifts of millions of galaxies.

### Thrusters
The thrusters are powered by cold nitrogen gas so as not to disturb any measurements. This is supplied by four high-pressure tanks, holding a seven-year supply.

### Dichroic plate (inside)
The dichroic plate splits incoming light, sending visible light to the VIS instrument and near-infrared light to NISP, allowing observations of both simultaneously.

### Star trackers
Three star trackers measure the telescope's attitude (the direction it's pointing) by comparing what it sees to a built-in star catalogue.

## How we can test dark energy

### Measure galaxy shapes
Light is bent by matter, so galaxy shapes are distorted if there's a clump of dark matter between us and them. Mapping dark matter helps pin down dark energy's influence.

### Detect supernovae
If a source of light moves away from us the wavelength stretches. This redshift shows how fast a Type Ia supernova is moving away from us, while its brightness reveals its distance.

### Examine the CMB
The Cosmic Microwave Background (CMB) is radiation emitted just after the Big Bang. It's so far provided backing for a universe containing both dark matter and dark energy.

### Look for new particles
If your lab equipment is sensitive enough you might be able to detect the minuscule effect of a 'fifth force' on atoms here on Earth. This small-scale experiment can be done in a short timescale.


Sunset over the Large Synoptic Survey Telescope, under construction in Cerro Pachón, Chile

a 3,200-megapixel camera – the world's largest. Currently under construction in Chile, its 8.4-metre (27.5-foot) diameter primary mirror will capture an image of the whole sky every three nights over a ten-year period.

And then there's the European Space Agency's Euclid telescope, which is expected to be launched into space in 2021. It will cover 15,000 square degrees of sky – that's ten-times the area of the Kilo-Degree Survey – observing a billion galaxies and peering 10 billion years into the past. The images it sends back to Earth will be spectacular – similar in resolution to those taken by the Hubble Space Telescope.

In preparation for the launch, Paniez Paykari is modelling Euclid to ensure the instrument performs as intended. A research associate at the Mullard Space Science Laboratory, she explains that while all measurements come with statistical uncertainty, Euclid will give cosmologists more precise data to work with. "In the past 20 years evidence from all probes has pointed to the existence of dark energy – that it's probably a cosmological constant but nothing more. If we can be exact with Euclid, we'll be able to tell if dark energy is constant or if it's dynamic."

What if the treasure trove of data from new observations, expected in the mid-2020s, sounds the death knell for the cosmological constant? One possibility could be that, despite passing every test thrown at it for decades, Einstein's general theory of relativity is wrong. Or at least that gravity may, in some circumstances, work differently than the theory describes.

"If we can be exact with Euclid, we'll be able to tell if dark energy is constant or if it's dynamic" **Paniez Paykari**

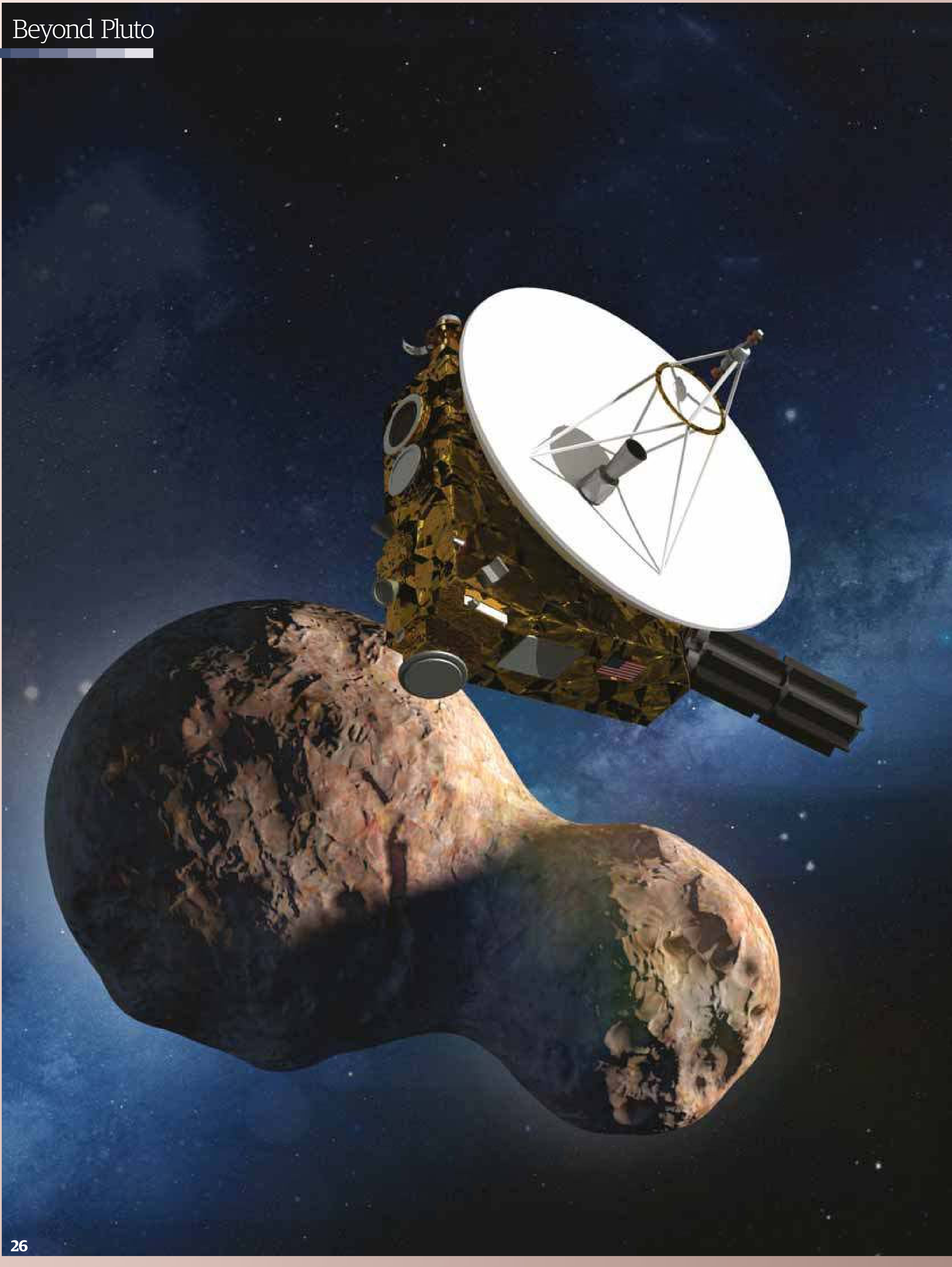
"It might be gravity is not attractive on all scales. If you put two things close to each other they will attract because of gravity, but it may be that if you put them far enough apart they will repel. It could be that gravity is repulsive or somehow needs changing on cosmic scales," says Kitching.

Many modified-gravity theories have been cooked up by theoretical physicists, and only more data will determine whether or not they're correct. By a quirk of fate, many of these models were ruled out last year thanks to a gravitational wave signal named GW170817.

"It came out of the blue," says Kitching. "A merger of two neutron stars produced a gravitational wave signal and a flash of light at the same time. These arrived [at Earth] at the same time too, which means that light and gravitational waves travel at the same speed."

At a stroke, all the modified-gravity theories that also predicted different speeds for light and gravitational waves bit the dust. But there are plenty left, and it's likely to be quite some years before the dark energy riddle is solved once and for all.


The Abell 370 cluster consists of hundreds of galaxies held together by gravity



# BEYOND PLUTO

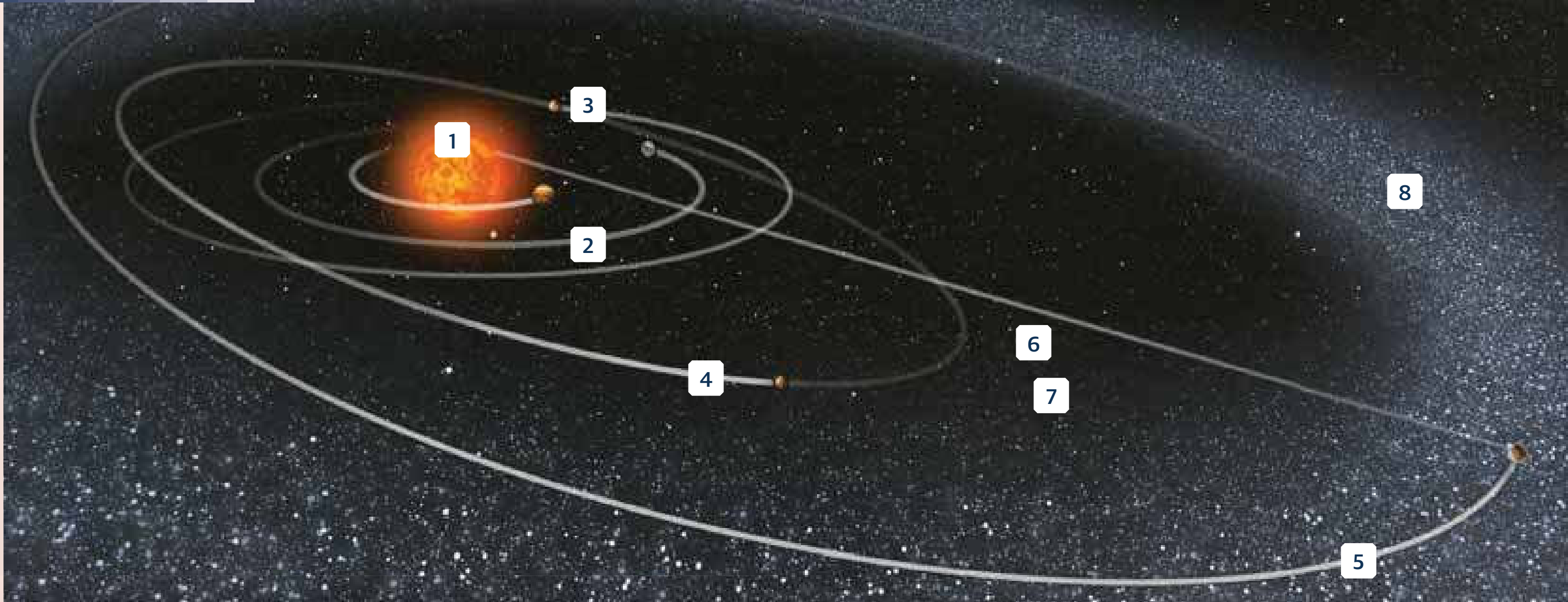
As NASA's New Horizons probe nears its second target, we investigate what's lurking at the edge of the Solar System

—Reported by Ian Evenden—

The constellation of Sagittarius, the Archer, is a common sight in the winter sky, easily recognisable by the 'teapot' asterism that makes up its front half. Look in the Archer's direction and you're staring into the centre of the galaxy, the Milky Way contributing the 'steam' from the teapot's spout.

With a home telescope you might see the Lagoon Nebula within Sagittarius, or a globular cluster such as Messier 54. If you have access to billions of dollars' worth of space telescope, however, you may discover other much smaller and fainter things.

This is just what happened in 2014 when the Hubble Space Telescope was surveying the area, hoping to find a new target for the New Horizons mission after ground-based telescopes had failed to




# Where is Ultima Thule?

**The Sun**

1 The influence of our local star falls quickly the further you travel away from it. At the Kuiper Belt it looks like a bright star and provides illumination like dim moonlight.

**Earth orbit – 150mn km (93mn miles)**

2 New Horizons left Earth on 19 January 2006, travelling faster than any spacecraft had previously to go directly into a solar-escape trajectory.

**Jupiter orbit – 778mn km (483mn miles)**

3 The probe passed Jupiter in early 2007, receiving a gravity assist that increased its speed and shortened its flight time by three years.

**Orbit of Neptune – 4.5bn km (2.8bn miles)**

4 Neptune's 'trojans' – small bodies that orbit at the same distance as the planet – were also considered for investigation.

**Orbit of Pluto – 5.9bn km (3.67bn miles)**

5 New Horizons' first target, which it passed in July 2015. It travelled roughly 12,500km (7,767 miles) above the surface and returned images.

**Orbit of Ultima Thule – 6.5bn km (4bn miles)**

6 The new target, a cold classical KBO made from material left over from the formation of the Solar System. New Horizons is expected to reach it on 1 January.

> "By observing KBOs up close we hope to learn a lot about how the early formation stages of the planets took place" **Dr Alan Stern**

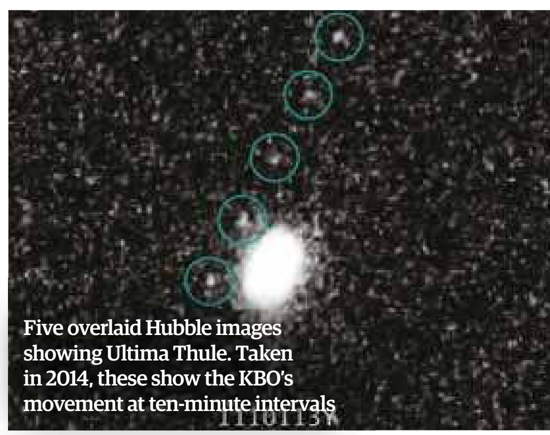
find anything there. Back then, NASA's mission to Pluto was still incomplete, but it was clear the probe would be heading in the direction of Sagittarius following its encounter with the distant dwarf planet and, if an even more distant object were found in its path, it could carry on and encounter that too. With plenty of plutonium dioxide on board to generate power the probe is expected to keep functioning for many more years, time enough to explore the outer reaches of the Solar System at over 58,000 kilometres (36,040 miles) per hour.

The object Hubble discovered was named (486958) 2014 MU69. The number in brackets is its minor planet number – we know of over half a million – while 2014 is the year of discovery. M is for the second half of June, and U64 indicates it's the 1,745th object discovered during those two weeks. Modern techniques and space telescopes are discovering a lot of objects. 2014 MU69 quickly picked up a nickname, Ultima Thule, as a result of a public vote. Thule, in Greek and Roman literature, was the furthest north you could go, often associated with Greenland or Iceland. The later addition of 'ultima', meaning 'furthest', was used to mean a place beyond the borders of the world.

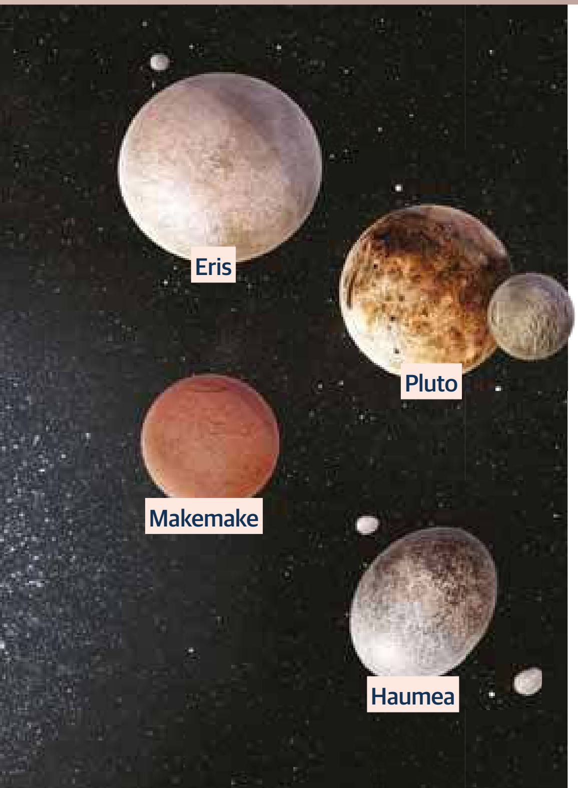
There are many thousands of unknown worlds out there at the borders of our Solar System beyond the orbit of Neptune, but very few were in the right place to be visited by New Horizons. Collectively known as Trans-Neptunian Objects (TNOs), they're dimly lit and enormously spread out, with distances of 1 Astronomical Unit – the distance from the Earth to the Sun – between them. The best known, Pluto, is the most massive known object in an area of space between 30 and 55 AU from the Sun, known as the Kuiper Belt.

We know of a few other big things in the belt – with two of them classified as dwarf planets like Pluto – and there's something heavier than Pluto too, the dwarf planet Eris, but it's three-times further from the Sun than the demoted ninth planet, and isn't classed as a Kuiper Belt object (KBO) thanks to its extreme distance – it falls into an area known as the Scattered Disc. Many scientists also believe there's evidence of a larger body in the orbits of smaller ones, but it hasn't been seen yet.

An object needs a single-body diameter of at least 300 kilometres (186 miles) to be considered a dwarf planet. Most known KBOs are much smaller than Pluto's 2,377-kilometre (1,477-mile) width, however.


Five overlaid Hubble images showing Ultima Thule. Taken in 2014, these show the KBO's movement at ten-minute intervals


New Horizons launches from Cape Canaveral Air Force Station, Florida, with a nine-year flight ahead of it before its encounter with Pluto




**Scattered Disc – 15bn km (9.3bn miles)**

**7** A subset of the Trans-Neptuian Objects, the disc contains at least one dwarf planet and is though to be the origin of the short-lived periodic comets.

**Oort cloud – 150bn km to 15tn km (93bn to 9.3tn miles)**

**8** Still unconfirmed, situated beyond the Sun's influence, this is thought to be the origin of the long-period comets.

There's Lempo, a binary system with at least one additional satellite and a total diameter of around 400 kilometres (249 miles), the same as Saturn's moon Mimas. It's named after the god of love from Finnish mythology, and like a lot of KBOs appears extremely red. Then there's Drac, only 90-kilometres (56-miles) across and named after Bram Stoker's famous count. It's notable because of its high inclination and the fact its orbit is retrograde – the opposite direction to most other objects.

Ultima Thule could be a binary system too, but with a diameter of just 30 kilometres (18.6 miles) it's a bit hard to make out from Earth. It was chosen as the new target because of its position – less fuel was required to reach it. A brighter, and therefore probably larger object was also considered, but the fuel needed to reach it would have left less in the tank for future manoeuvring.

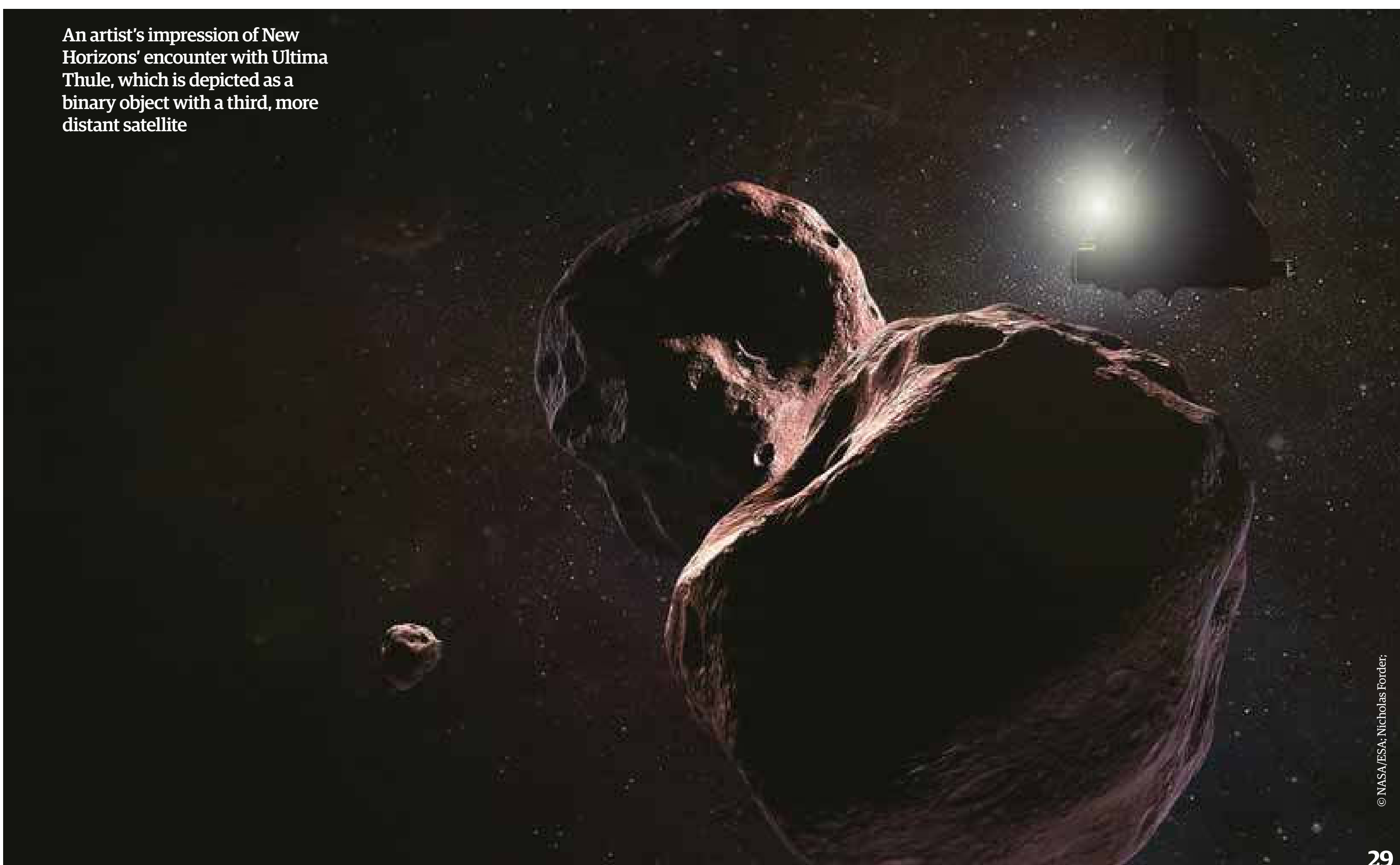
But why worry about something so small and far away? Studying KBOs like this tells us about the way the Solar System was a long time ago. "The belt is analogous to the Solar System's attic," says New Horizons' principal investigator Dr Alan Stern. "It's an ancient region, very far from the Sun, which has been preserved in a deep freeze. It's the equivalent of an archaeological dig into the history and formation of the planets. So scientifically it's a gold mine, and by going there with a spacecraft and observing KBOs up close, like we'll be doing with


An image from April 2017 shows Ultima Thule as an unrecognisable dot among background stars – it's identified by its motion

Ultima, we hope to learn a lot about how the early formation stages of the planets took place."

And that's not all, as the interactions of the small objects out there can tell us a lot about the movements of big objects. Really big ones. "What we know of the Trans-Neptunian region is that it's the leftover remnants of the objects that didn't make it into being planets," says Dr Michele Bannister, a post-doctoral researcher at Queen's University Belfast, who helps discover minor planets as part of the Outer Solar System Origins Survey. "These little rocky and icy worlds were formed in the initial disc of material around the Sun, the ones that never grew up into being planets in their own right. Since then they've been sculpted by changes in the orbital positions of the giant planets, particularly Neptune."

The idea that planets move around rather than just placidly orbit the Sun can be hard to process given the enormous size and mass of the outer planets, but according to the Nice model of Solar System formation – named after the place in France, not merely because it's pleasing – as the Solar System gathered together from its protoplanetary disc, everything formed much closer to the Sun. The outer edge of the Kuiper Belt was once 30AU from the Sun instead of 55, and Uranus was the outer planet instead of Neptune. There's even a hypothesis that there could have been a fifth giant


An artist's impression of New Horizons' encounter with Ultima Thule, which is depicted as a binary object with a third, more distant satellite

# New Horizons meets Ultima Thule

What will happen when the spacecraft hurtles past the mysterious object at the edge of the Solar System

**22 October 2015**
After leaving the Pluto system New Horizons fires its thrusters for about 16 minutes to begin its manoeuvre toward Ultima Thule.

**25 October, 28 October and November 2015**
Three more targeting burns before the craft goes back into hibernation.

**5 December 2017**
Images of Kuiper Belt objects 2012 HZ84 and 2012 HE85 break Voyager 1's record for images taken the farthest from Earth. New Horizons will break this record again and again.

**9 December 2017**
A short, 2.5-minute engine burn guides the probe more accurately to its target, setting the record for the most distant course correction manoeuvre from Earth.

**5 June 2018**
The spinning probe comes out of hibernation again and stabilises itself. It reports its health status to ground control.

**16 August 2018**
New Horizons' cameras detect Ultima Thule, still 172 million kilometres (107 million miles) away.

**25 December 2018**
The core phase of the mission begins a week before the encounter; data takes six hours to return to Earth.

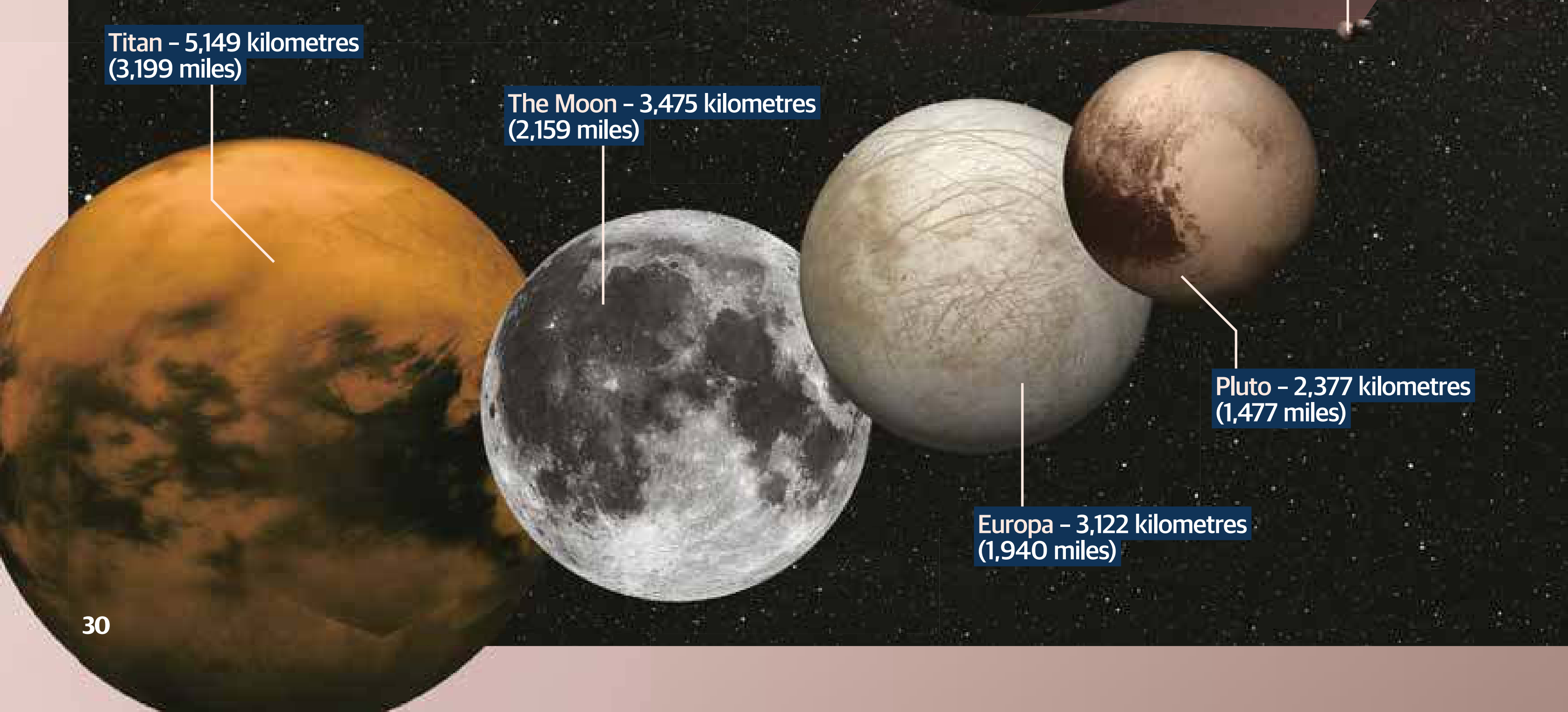
**1 January 2019**
The probe makes its closest approach to Ultima Thule, though the exact distance has yet to be decided.

**9 January 2019**
New Horizons will begin spinning again as it leaves Ultima Thule behind, but will continue to send data back all year.

**2026 at the very earliest**
New Horizons nuclear batteries will stop providing power.


## Size comparison

We're not quite sure yet how large Ultima Thule is, or even if it's one object or more, but telescopic surveys have put its average diameter in the ballpark of 30 kilometres (18.6 miles). Here's how that compares with other worlds



planet, ejected from the Solar System following an encounter with Jupiter.

Gravitational interactions between the four giants we know of led to Neptune moving outwards past the orbit of Uranus, producing the Kuiper Belt we see today. "What we see there today are materials from that initial disc," says Bannister. "Some of them are familiar, like water ice and rock, but some of them are unfamiliar, like kitchen cleaning chemicals you have under your sink, in solid form."

And even though it's called a belt, don't imagine it's completely flat. "A lot of the objects have never had anything happen to them; they're on round, flat orbits, but a lot of them have had energy put into them," continues Bannister. "They can be a lot more eccentric; their orbits are long, thin ellipses and they're tilted compared to the plane of the Solar System. Some of them are in an orbital ballet with Neptune, called a mean motion resonance, where Neptune goes around the Sun three times for every two times one of these objects goes round - that's the resonance Pluto is in. A lot of the objects are in places where they can do this, and that resonant objects exist at all when the spaces in between are free of objects is a signature that Neptune migrated outwards in the early Solar System."

Ultima Thule is one of the less eccentric objects, and is not in a resonance with Neptune. Known as a 'classical' KBO, it's also part of the 'cold' population, which means it has never received any energy from collisions or gravitational interactions. It's just been sitting there, doing relatively little, since the Solar System formed. Much of what we know about it comes from Hubble observations, or from occultations where the object passes in front of a background star. The dip in the star's brightness tells us about what's blocking it, and three occultations by Ultima Thule in 2017 were studied by a special group of astronomers formed by the New Horizons team. This study of occultations is the same process that is used to observe exoplanets around distant stars, but even with this data Ultima Thule remains a mystery.

"We don't know if it's two objects, or if it's binary, but we know its shape is not round," says Bannister. "Binary systems are very common in the population to which this little world belongs, and this ties directly into how they formed. A Solar System starts off being made of dust and gas, and this starts forming little objects, and they have to get over about a metre in diameter and suddenly they're full-on asteroids that can start accreting material much, much faster. This whole process is something people are very actively working to understand, but binary objects might be implying that, when you initially make little worlds, you make them binary, so it tells us a lot about what physics to put into simulations of how planets are formed."

## What's more Ultima than Thule?

Principal investigator Alan Stern reveals what the future holds for NASA's distant spacecraft

***What is the future of New Horizons?***
In January, after the Ultima Thule flyby, we will know precisely how much fuel is left, and then later in 2019 we will plan another search. Probably not with Hubble this time, but with our own telescopes that are onboard New Horizons. And we won't begin that search until much later, until 2020, because our spacecraft memory will be full of data from this flyby, and we have to send all of that back to Earth first. It will take us until about August or September of 2020 to finish downloading all of the images, the spectra and other data from the Ultima flyby. Then we will be in a position to start thinking about the next search for a target. We won't leave the Kuiper Belt until approximately the year 2027, so we have lots of time.

***What might the new target be like?***
It won't be another cold classical KBO, because we will have passed beyond that region. It will be something from the very distant Kuiper Belt, and it will have something else to teach us.

***What's out there in the distant Kuiper Belt?***
It's actually a mystery. The further things are the fainter they are, because they're not strongly illuminated by the Sun, and we know less and less. But the instruments we have on New Horizons were built to operate in those lower light levels, and the spacecraft and the payload are fully capable of conducting another flyby years from now. Everything in the Kuiper Belt is spread out - that's why we call it 'space' - there's no probable chance that we would crash into an object by accident.

***Do you think there are new planets to be discovered in the belt?***
Everything I see scientifically indicates that the answer is yes. Probably many of them. We don't have enough fuel to fly to one, but if one were discovered from Earth then we could use our telescopes on board, and potentially learn things you couldn't learn from Earth. But first you've got to know that they're out there and where they are.

> "I think that this dataset is something that's going to be valuable scientifically for decades to come" **Dr Alan Stern**

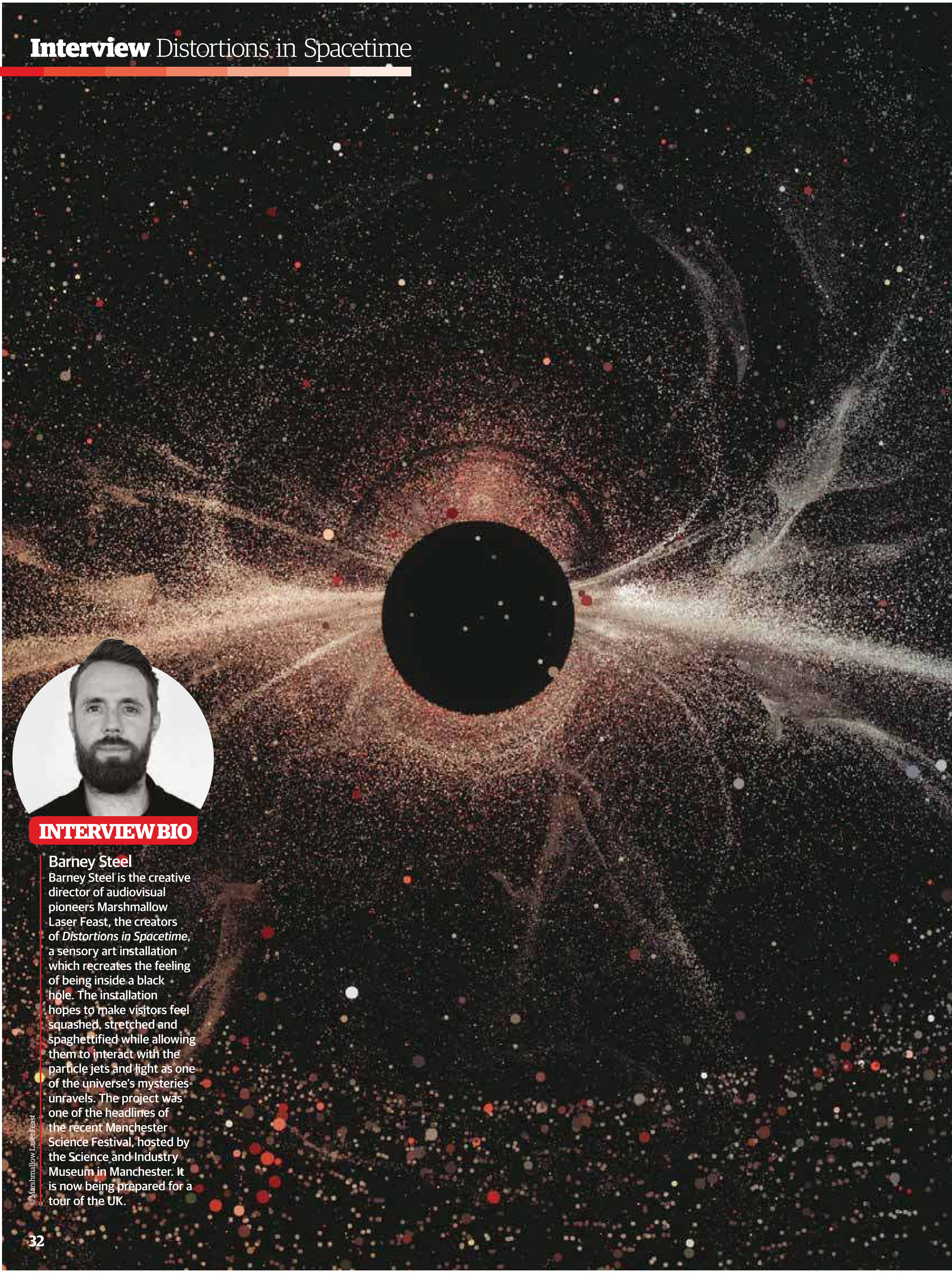


**An artist's impression of the New Horizons probe, seen approaching Charon in the Pluto system**

Whatever Ultima Thule is like, New Horizons is well equipped to tell us all about it, as the startling images of red-and-white plains and mountains on Pluto showed. "We have a very powerful set of seven scientific instruments," says Stern. "They will map its surface composition, search for an atmosphere, search for satellites, search for rings and make other kinds of studies. And I hope that we put together a very complete picture of what this typical Kuiper Belt object is like, because not only is this the first time that an object like this has been explored, but nobody's planning another mission out to the Kuiper Belt, so I think that this dataset is something that's going to be valuable scientifically for decades to come."

How long New Horizons can carry on sending back this kind of remarkable data is limited by the power and fuel supplies on the spacecraft, as well as the availability of suitable targets in its path. When you're travelling over 58,000 kilometres (36,040 miles) per hour, changing direction isn't easy.

Stern isn't worried about the future, however. "We have a very healthy spacecraft," he says. "We have the fuel and the power in our nuclear battery to run it for at least 15 years, maybe 20 years. If NASA continues to fund it, if NASA judges that it's scientifically worthwhile, this spacecraft will be operated into the mid-2030s or later. It's very much like the Voyagers which finished their exploration of the planets in the 1980s, but are still returning useful scientific data 40 years after launch."



## INTERVIEW BIO

**Barney Steel**

Barney Steel is the creative director of audiovisual pioneers Marshmallow Laser Feast, the creators of *Distortions in Spacetime*, a sensory art installation which recreates the feeling of being inside a black hole. The installation hopes to make visitors feel squashed, stretched and spaghettified while allowing them to interact with the particle jets and light as one of the universe's mysteries unravels. The project was one of the headlines of the recent Manchester Science Festival, hosted by the Science and Industry Museum in Manchester. It is now being prepared for a tour of the UK.

# EARTH'S BLACK HOLE

If you've ever wondered what it would be like to fall into a black hole, then you're not alone. Artists from Marshmallow Laser Feast considered the very same experience and came up with an absorbing exhibit that's now set to tour UK art galleries and museums

**Where did the idea for *Distortions in Spacetime* come from?**
*Distortions in Spacetime* is part of our larger body of work called 'The Scale of Things', which investigates experiences beyond the limits of perception and scales beyond imagination. The backbone of it explores science as a window to the world beyond human perception. It's based on scientists having many different instruments that can peer into the broader spectrum of reality, such as the Hadron collider, LIGO [the Laser Interferometer Gravitational-Wave Observatory] and the Hubble Space Telescope, which has imaged galaxies that are now believed to have formed in the first 500 million years following the Big Bang.

We normally digest these scientific stories through images and words, but our interest is in the multi-sensory immersive experience of these stories – essentially engaging all of the senses and simulating a perspective of reality that no human has ever experienced. It fits in well with our previous project 'In The Eyes Of The Animal', which was about animal perceptions and seeing the world through their eyes. In this case the whole world is our source of inspiration, and it allows us to feed into the technological revolution that's happening at the moment.

**Is it important to experience as well as learn about subjects such as black holes?**
I guess the opportunity to experience something like a black hole only becomes available when the technology to simulate it exists. We have known about them for a long time, but it's the evolution of real-time graphics and computer game technology that enables us to explore what an experience might be like. This goes hand-in-hand with virtual-reality technology – the ability to hack the senses and simulate a signal the brain accepts as real allows us to simulate experiences our sensory bodies could never really have. There is a difference between knowing something and experiencing, and it's this area of simulated experience that excites us. We hope to create a sense of awe which can lead to curiosity and learning. The American theoretical physicist Richard Feynman said it well: "A scientific understanding only ever adds a sense of wonder, it never subtracts." And that is true for us.

**Before you began the project did you have any background or interest in space?**
Myself and most of the gang at Marshmallow Laser Feast share an interest in space and the big mystery of where we came from.

**Do you have any particular influences?**
We were inspired by great communicators like Richard Feynman and Carl Sagan who served up the wonder of science in a way that the masses could digest. I love the Carl Sagan quote: "The origin and evolution of life are connected in the most intimate way with the origin and evolution of the stars." It's mind-bending that most of the elements, the ingredients for life, were not created in the Big Bang and were cooked in the hearts of massive stars and spewed out into the cosmos in supernovae explosions. This life-creating process also created black holes, the furthest place from life in the known universe.

**Did it entail having to learn quite a lot about black holes?**
Yes, the project started about two years ago and spent time investigating and learning using general relativity as the starting point. Albert Einstein had the imagination to translate phenomena in the cosmos to things that he could experience as a man on Earth. So he imagined what it would be like to ride on a beam of light and he dreamed up the idea of having an entire physics laboratory in a falling elevator. He had a capacity to connect two worlds. That's where our journey started, trying to

"We were inspired by great communicators like Feynman and Sagan"

understand general relativity which – as everyone knows – is pretty lofty stuff, especially if, like me, you're not a mathematician. I think I've got as close as I can to understanding as an enthusiast, though.

**What kind of facts did you find that piqued your interest?**

We tried to learn what it would be like to fall into a black hole and, for this, we found Neil deGrasse Tyson told it best. He had a great series of lectures called *My Favorite Universe* which can be downloaded through Audible, and we found that he had a beautiful and inspiring way of describing death by black hole. One of our starting points, however, was time dilation – understanding space and time as two dimensions of the same thing and how that 'fabric' of space-time is flexible, deformed by the mass within it.

We considered basing it on two people using virtual reality. We were going to have people pretend to be with a friend close to a black hole and explore how, when talking to him as he walked towards the black hole, his voice would start to slow. In this way, the aim was to give an understanding of how time slows down by observing the interaction between yourself and another person in relation to the centre of the black hole. As the piece progressed, however, we adapted the idea to make it work better at science festivals where you need to get a certain number of audience members through. It became much more about the phenomenon and experience of falling into a black hole.

**How do you project a feeling of being in a black hole?**

The experience starts in darkness at the outer edges of the black hole's gravity well. Audience movement creates anthropomorphic dust clouds inspired by the raw elements that make up the human body. Black holes are black – they emit no light – but they become visible by their gravitational influence on the environment around them. Your elemental particles slowly fall into orbits, defining the black hole.

This journey is much like flowing down a river that gets steadily more violent before reaching the point of no return: the waterfall or event horizon. Just before you get sucked in you pass through the photon sphere, a log jam of light tracked in orbits around the event horizon. In theory, if you could stand still at this point you would see the light from the back of your head as it orbits the black hole and smacks you in the face.

We then wanted to explore spaghettification, the process where objects are stretched and ripped apart by gravitational forces when they fall into a black hole. It's essentially to do with the tidal force – the difference of pull between your feet and your head – breaking you into all of these atoms and causing you to end up in some kind of string en route to the singularity. Then we explored the Doppler effect and how different frequencies of light travel at slightly different wavelengths. So when you're dealing with a gravitational force that exceeds the speed of light, you start to see white light breaking through its elements. We also played with gravitational lensing to add to the process and experience.

**Before visitors enter the black hole they are shown an audio-visual presentation. Was it important to explain all of these concepts?**

Because *Distortions in Spacetime* was a collaboration with the Manchester Science Festival, they really

**It's possible to wave your arms around while moving back and forth within the environment in order to interact with the elements around you**

**The art installation explores the event horizon – a defined edge from which nothing is able to escape**


The installation formed a key part of the recent Manchester Science Festival and it's due to tour the UK

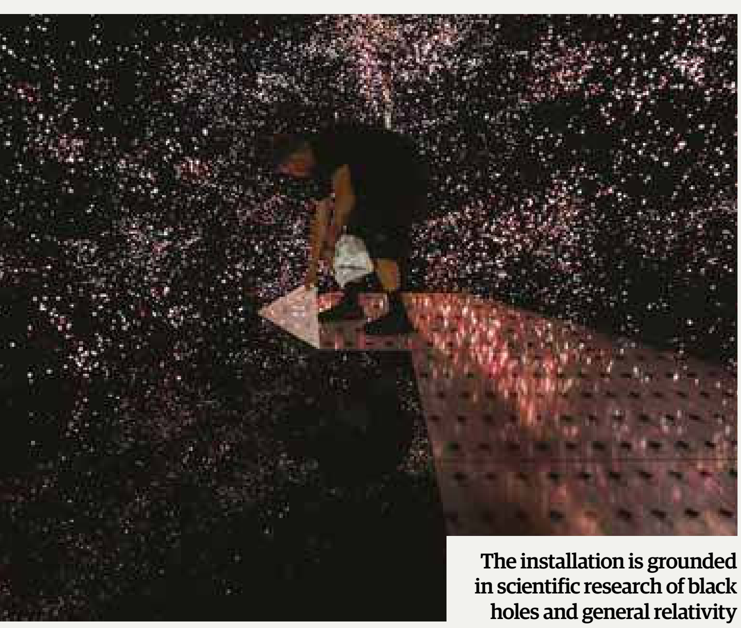
wanted to make it family-friendly, so part of the commission was to explain the concept. We had the challenge of explaining General Relativity to seven year olds and working closely with Matthew allen, our science advisor and science communicator. We got to a nice place.

**What's the reaction been like so far?**
People like it. We used mirrors to create a sense of floating in the void and that appears to go down well – it removes people from the sensory norms of a gallery space having a floor, ceiling and walls and it helps to make the experience feel more disorientating.

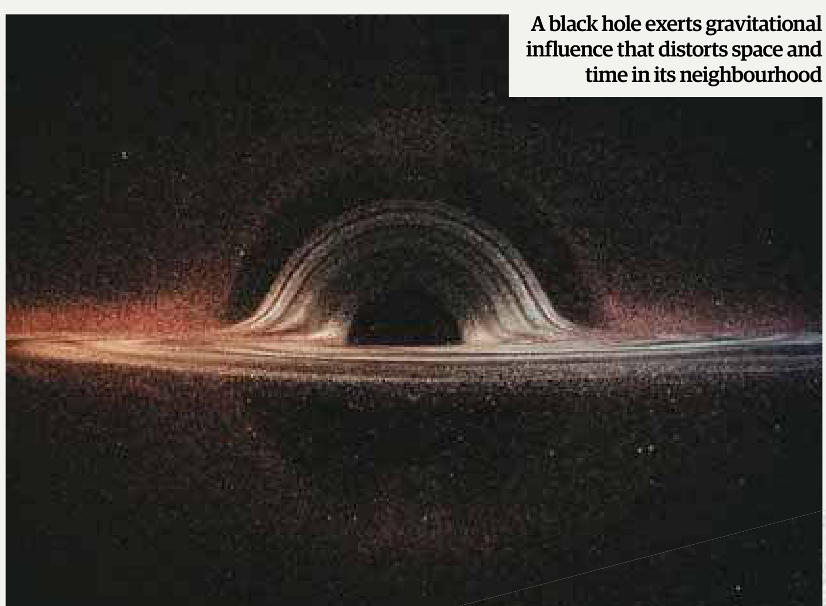
**What's happening next with the installation?**
We're in discussions with different places but nothing's confirmed yet. We will be posting venues on our website, which is **marshmallowlaserfeast.com,** as well as on our Facebook page [**facebook.com/marshmallowlaserfeast**]. We're also updating all of our work in progress on Instagram [**@marshmallowlaserfeast**]. The work is built as a 360-degree virtual world that can be unwrapped onto full domes, virtual reality and other 360-degree formats.

**So it would work well in virtual reality?**
Yes. One day. Absolutely. That's definitely the vision. We're doing a piece at the moment which opens at Saatchi Gallery in London in December. It will run for two months and involves six people in virtual reality, all interacting with each other within the experience. There are no cables so people can explore quite a large area, which is a big technological leap forward that we want to continue exploring. When we were designing Distortions in Spacetime that technology didn't exist. The future of this technology and its ability to mould perception is really exciting, and our guiding compassion is to make experiences that reconnect the audience to the wonder of reality, not detach them.

"Most of the gang at Marshmallow Laser Feast share an interest in space and the big mystery of where we came from"



The installation is grounded in scientific research of black holes and general relativity



A black hole exerts gravitational influence that distorts space and time in its neighbourhood

# THE REUSABLE LUNAR LANDER

## Lockheed Martin has announced a new single-stage design that would work well with NASA's Lunar Gateway

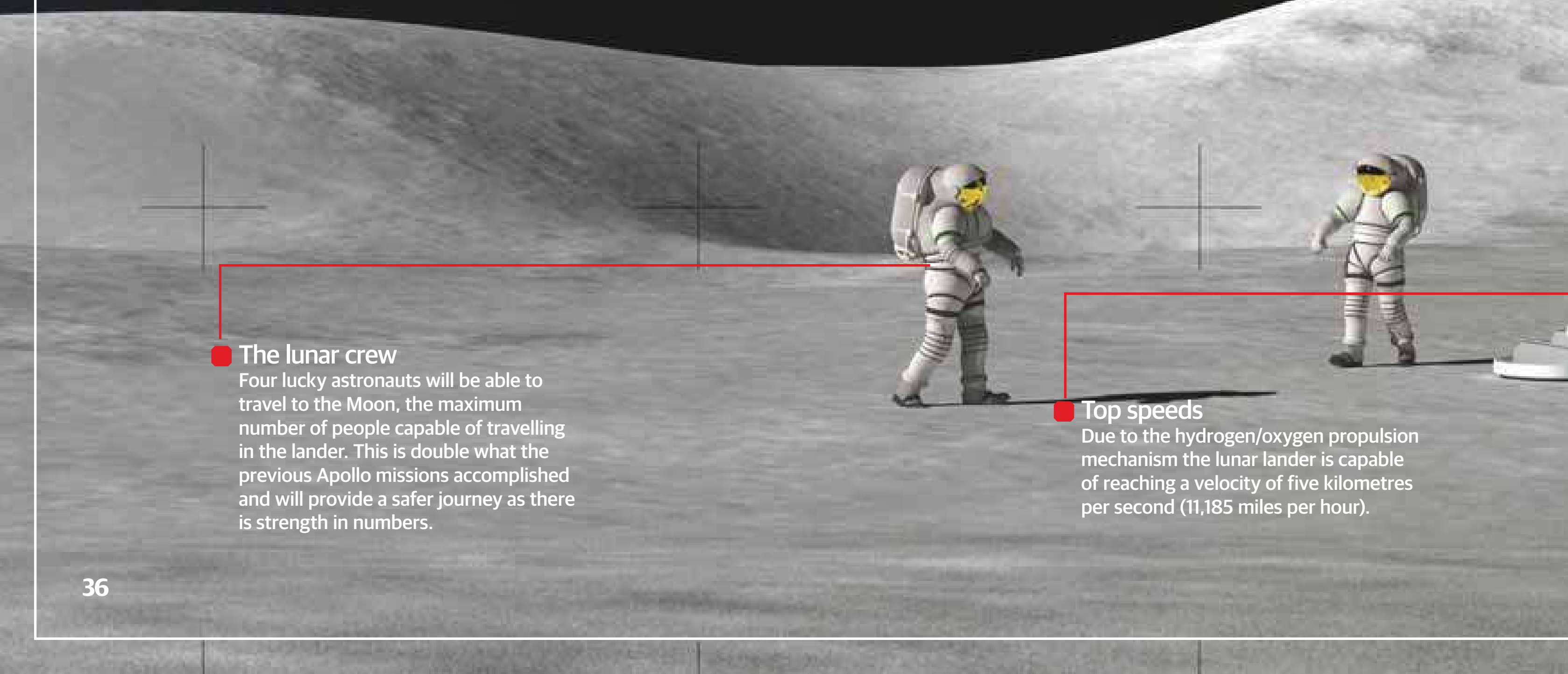
Space sustainability is forever in the minds of scientists and engineers alike, and they are working together to improve the feasibility of numerous lunar trips. Space exploration has shown we are capable of taking man to the Moon and landing on it successfully. It has also revealed that it is possible to build and maintain a space station. When you combine this knowledge and extrapolate its capabilities for the future you get NASA's proposed Lunar Gateway, which will advance human's attendance in space, particularly within the vicinity of the Moon.

A recent announcement was made at the 69th International Astronautical Congress (IAC) in Bremen, Germany, where Lockheed Martin revealed its new concepts for an exciting reusable Moon lander that can work alongside NASA's proposed lunar outpost. This lunar lander furthers the possibility of sustainable space travel to the Moon and could even provide a valuable service for future missions to Mars. The key to this lander is its reusability, and with a hydrogen/oxygen propulsion system it is possible that the proven presence of water ice on the Moon could be vital for multiple visits.

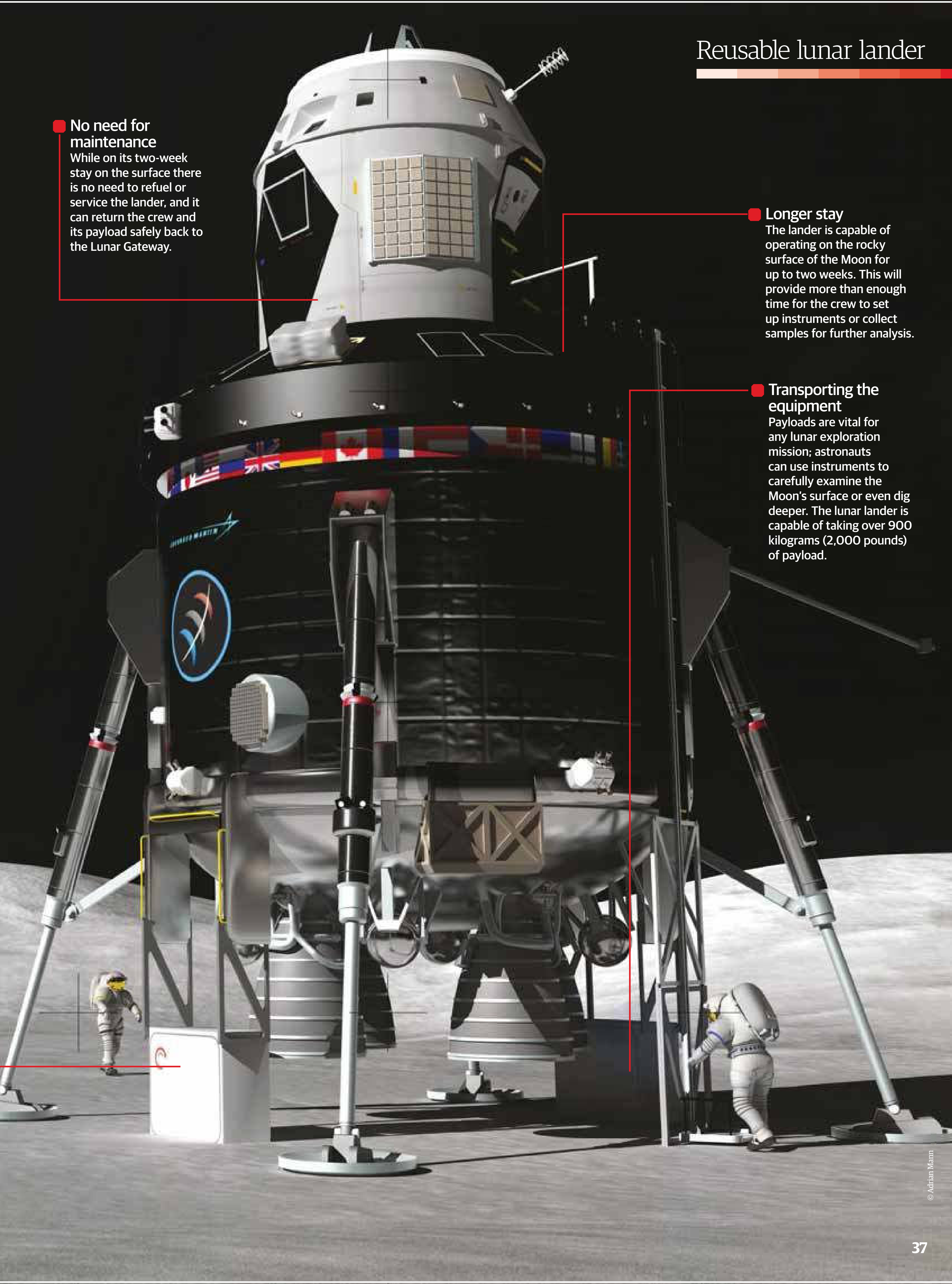
"NASA asked industry for innovative and new approaches to advance America's goal of returning humans to the Moon and establishing a sustainable, enduring presence there," says Lisa Callahan, vice president and general manager of Commercial Civil Space at Lockheed Martin Space. "This is a concept that takes full advantage of both the Gateway and existing technologies to create a versatile, powerful lander that can be built quickly and affordably. This lander could be used to establish a surface base, deliver scientific or commercial cargo and conduct extraordinary exploration of the Moon."

This crewed lander will consist of a single-stage, fully reusable system that will include technologies and systems taken from another of NASA's projects, the Orion spacecraft, which is being built for the human exploration of deep space. This lander will accommodate four people and also over 900 kilograms (roughly 2,000 pounds) of payload as they journey to the lunar surface. It will be able to stay on the Moon's surface for up to 14 days without refuelling before returning back to the Lunar Gateway.

The benefits of being able to access multiple sites with a reusable lander has incredibly positive consequences for international, commercial and scientific communities. After the astronauts have made their visit to the Moon and conducted their experiments and other such business, the lander will then launch back to the Lunar Gateway where it can be refuelled, serviced and parked until its next mission. Much like how the International Space Station is key to preparing for long-term deep space travel, Lockheed Martin's lander will be essential in preparing for an eventual Martian touchdown, as both the Moon and Mars have a much weaker gravity and also exhibit an essentially non-existent atmosphere.



# Reusable lunar lander



### No need for maintenance
While on its two-week stay on the surface there is no need to refuel or service the lander, and it can return the crew and its payload safely back to the Lunar Gateway.

### Longer stay
The lander is capable of operating on the rocky surface of the Moon for up to two weeks. This will provide more than enough time for the crew to set up instruments or collect samples for further analysis.

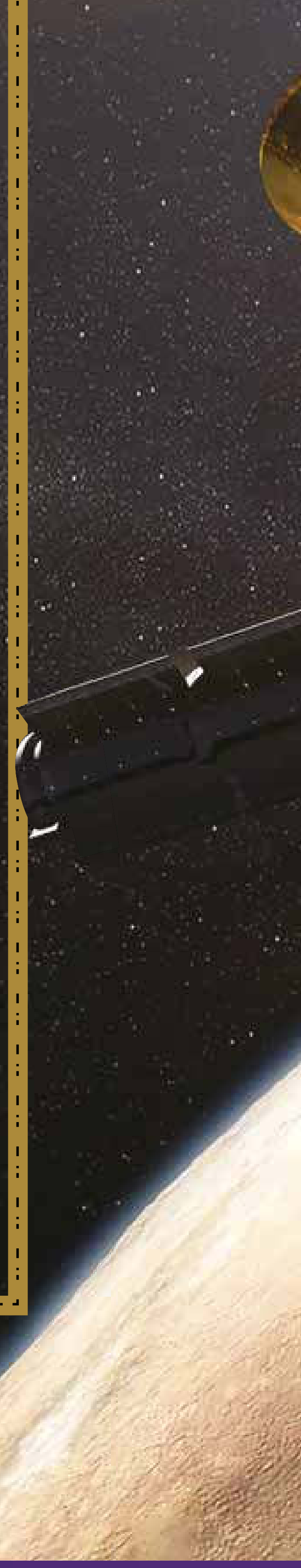
### Transporting the equipment
Payloads are vital for any lunar exploration mission; astronauts can use instruments to carefully examine the Moon's surface or even dig deeper. The lunar lander is capable of taking over 900 kilograms (2,000 pounds) of payload.

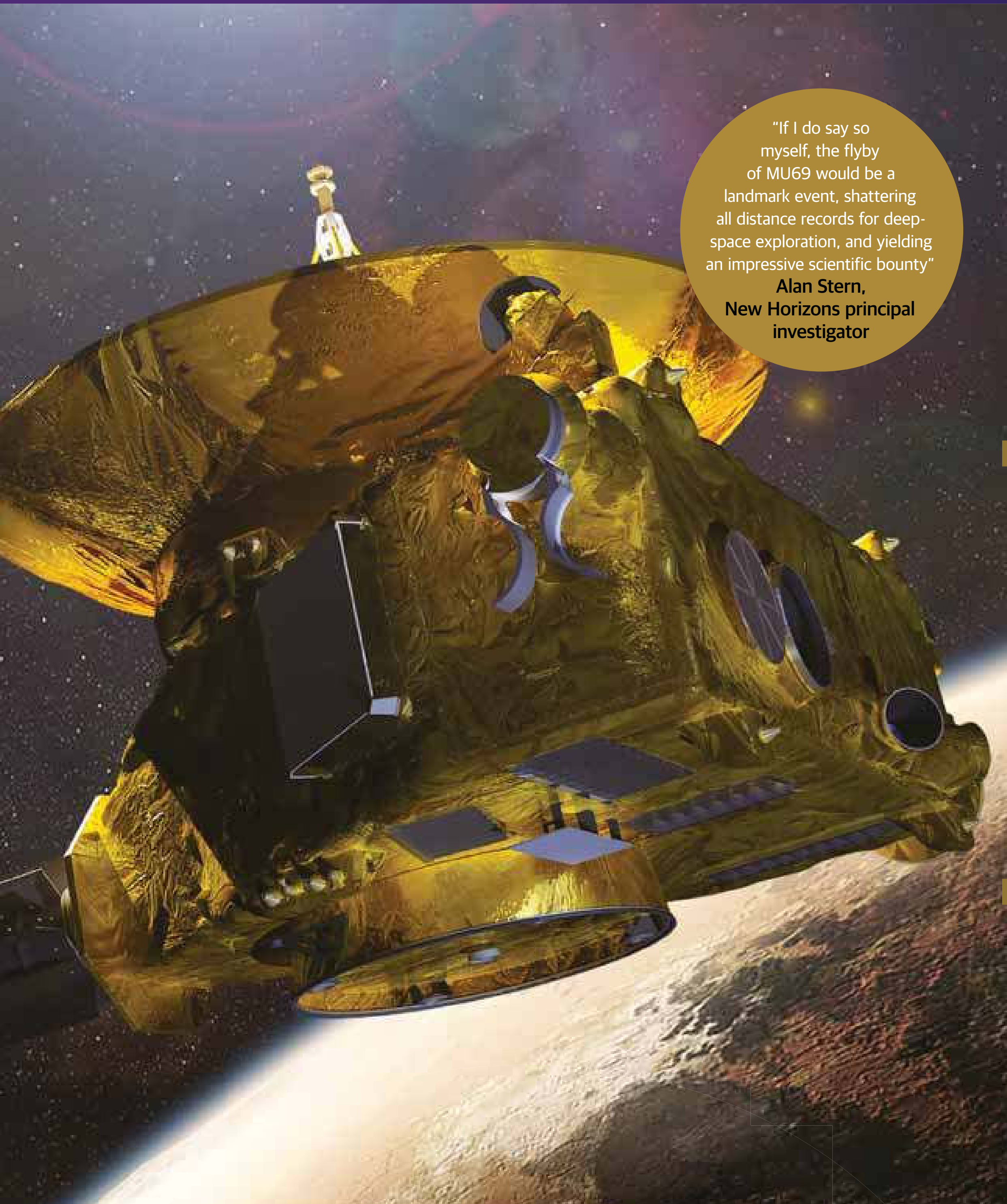
# 2019 SPACE EVENTS YOU CAN'T MISS

## Clear your calendars - these are the stargazing events and mission launches to look forward to next year

Written by Nikole Robinson

As the years pass and science and technology advance we see more and more missions launched that harness these leaps forward to expand our knowledge of space. As we head into 2019 things are no different, with a number of exciting launches planned over the year. This year a rise in commercial launches is highlighted with both unmanned and manned test flights planned by Boeing and SpaceX. Commercial space travel will change the way we explore the universe and lead us down the path of making space more accessible, so its development is imperative. For astronomy fans there's plenty in store too, with meteor showers year round and the four giant planets coming to opposition. Here's what to look out for over the next 12 months.





> "If I do say so myself, the flyby of MU69 would be a landmark event, shattering all distance records for deep-space exploration, and yielding an impressive scientific bounty"
> **Alan Stern, New Horizons principal investigator**

*01 January*
## New Horizons meets 2014 MU69

Three-and-a-half years ago New Horizons flew 12,500 kilometres (7,767 miles) above Pluto, gifting us close-up images of the dwarf planet and its heart-shaped Tombaugh Regio, but its mission was far from over as it headed deeper into the Kuiper Belt. NASA decided the next target in its sights would be (486958) 2014 MU69, nicknamed Ultima Thule by the New Horizons team, which lies about 1.6 billion kilometres (1 billion miles) beyond Pluto.

Due to arrive at the beginning of the year, this will be the furthest object visited by a spacecraft and will provide invaluable science about Kuiper Belt Objects. New Horizons is planned to fly within 3,540 kilometres (2,200 miles) of 2014 MU69, using its array of onboard tools to map its surface, temperature and composition and determining how this primal object evolved.

*06 January*
## Partial solar eclipse

Although not as revered as a total solar eclipse, a partial eclipse is still an awe-inspiring sight. This one will be visible in parts of eastern Asia, but will be best viewed from northeast Russia where it will reach 62 per cent coverage. If you are observing the event through a telescope make sure that you are using a solar filter, and use eclipse glasses or the pinhole method to create a reflection of the eclipse if observing with your eyes.

*21 January*
## Supermoon lunar eclipse

The first of three consecutive supermoons in 2019 – when the full Moon is closest to Earth in its elliptical orbit and therefore appears larger in the sky – January's full Moon will also coincide with a total lunar eclipse in some parts of the world, taking on a dark-red colour as the Moon passes behind the shadow cast by the Earth. The eclipse will be visible across North and South America and in the most extreme western parts of Europe and Africa. The second supermoon of the year will occur on 19 February and the third on 21 March.

*January*

# SpaceX Dragon 2 uncrewed testing

SpaceX's Dragon capsule made history in 2012 as the first commercial spacecraft to rendezvous with and attach to the International Space Station (ISS), its success meaning a contract for resupply missions was founded between SpaceX and NASA under its Commercial Resupply Service.

Development on the Dragon 2 capsule actually began before its successor's rendezvous in 2010, but it wasn't publicly unveiled until 2014. Updates to the craft include larger windows, redesigned solar arrays and improved flight computers and electronics. Both cargo and crew versions have been designed, and January will see the craft attempt the same ISS approach and docking procedure as its predecessor.

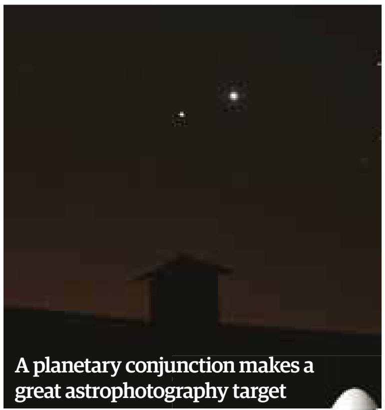
"Updates include larger windows and improved flight computers"

"As we get closer to launching human spacecraft from the US, we can be more precise in our schedules"
**Phil McAlister, director of Commercial Spaceflight Development at NASA**


*22 January*

# Conjunction between Venus and Jupiter

An astronomical sight to wake up early for, the pair of bright planets will be visible above the horizon after 4:51am GMT, fading with the rising of dawn at around 7:30am. Venus will be glistening brightly at a magnitude of -4.3, outshining gas giant Jupiter and its magnitude of -1.9. Both will be in the constellation of Ophiuchus and share the same right ascension, with Venus passing just 2°26' north of Jupiter – in reality there is over 588 million kilometres (365 million miles) between the two planets at their closest point to one another.


**A planetary conjunction makes a great astrophotography target**

*January to March*

# India shoots for the Moon

India became the fourth country to place its flag on the Moon in 2008 when the Chandrayaan-1 spacecraft deployed its Moon Impact Probe in November that year, making a successful landing near the Moon's south pole. A follow-up mission has been planned for some time in Chandrayaan-2, but delays have pushed the proposed launch to 2019, with the Indian Space Research Organisation (ISRO) hoping to launch as early as January.

Chandrayaan-2 comprises of an orbiter, lander and rover, all developed in India. The lander and rover will be aimed at a high plain near the Moon's south pole and will attempt to make a soft landing there in order to study the Moon up close. The mission is planned to launch on a Geosynchronous Satellite Launch Vehicle Mark III.


**India was the fourth country to land a craft on the Moon**


*March*

## Boeing's Starliner takes off

The CST-100 Starliner – with CST standing for Crew Space Transportation – is Boeing's answer to the Commercial Crew Development program, designed to pilot crews to the ISS and any future space stations. Similar in concept to Lockheed Martin's Orion module, the 4.56-metre (15-foot) capsule is designed to carry larger crews of up to seven people, though for this primary test it will launch unmanned. Like the Dragon 2 craft designed by SpaceX it will be reusable, with an estimated ten-mission usage.

The craft will perform its first test in March 2019, attempting to rendezvous and connect with the ISS using its NASA Docking System before returning to Earth for further analysis.

*Early 2019*

## CHEOPS will further exoplanet knowledge

A combined mission between the Swiss Space Office (SSO) and the European Space Agency (ESA), the CHaracterising ExOPlanets Satellite (CHEOPS) is a planned space telescope that will aid in the study of known exoplanets discovered in previous missions. Launching from the Guiana Space Centre in Kourou, French Guiana, its main goal will be to take measurements of exoplanets which have already had their mass estimated by ground-based surveys.

By knowing the radii and the mass of an exoplanet through CHEOPS data scientists will be able to determine the density of the exoplanets, hinting at their composition, which will make them easier to characterise. CHEOPS will also be able to search for shallow transits of planets by measuring photometric signals.

*June*

## SpaceX sends a crew to the ISS

Depending on the success of the uncrewed docking test planned to take place in January, the first crewed test flight of the Dragon 2 capsule, dubbed SpaceX Demonstration Mission 2 (SpX-DM2), is planned to go ahead in June.

It was announced on 3 August that NASA astronauts Bob Behnken and Doug Hurley had been selected as the test crew for this mission, the third spaceflight for both men, with Kjell N. Lindgren serving as the backup astronaut. Planned to launch on a Falcon 9 Block 5 from the Kennedy Space Center in Florida, if kept on schedule this will be the US's first manned flight since the Space Shuttle Atlantis mission STS-135 that launched in July 2011.

*10 June*

## Jupiter reaches opposition

The king of the Solar System will be at its closest approach to Earth and fully illuminated by the Sun, reaching a magnitude of -2.6 in Ophiuchus, making this the best opportunity to set your sights on it. Jupiter will be clearly visible to the naked eye as an orange-tinted star, reaching its highest point above the horizon at 1:01am BST. A good pair of binoculars will reveal Jupiter's four largest moons, looking like smaller stars within the planet's vicinity and creating a wonderful target for astrophotography. A medium-sized telescope should reveal some contrast in the swirling cloud bands.

Jupiter and its Galilean moons will be well placed for observation

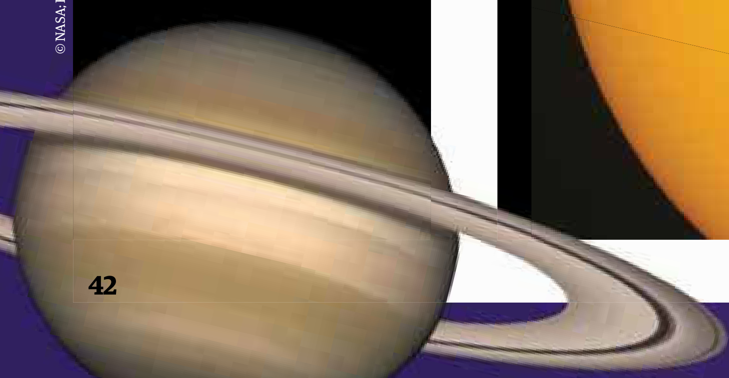
*02 July*
## Solar eclipse

After the show-stealing Great American Eclipse passed over the entire continent of North America in August 2017, this event may not seem as spectacular, but it will still be a magnificent sight to behold if you happen to be in the path of totality in central Chile or Argentina. A total solar eclipse is a rare phenomenon caused by the Moon – being the same apparent size from Earth as our Sun – passing in front of the Sun and blocking its light. This reveals the mysterious, hot halo of the Sun's corona.

Neighbouring South American countries will also be treated to a partial solar eclipse where the Moon does covers part of the Sun's face, creating a 'bite' out of its glowing disc.

*09 July*
## Saturn reaches opposition

Saturn will be well placed for observation in Sagittarius, fully illuminated by the Sun as it makes its closest approach to Earth. Even though Saturn will still be over nine-times the Earth-Sun distance it will be visible to the naked eye as a magnitude 0.1 golden-hued star. On top of this, Saturn's rings will be inclined at an angle of 24° to us – almost the maximum inclination they can have – so viewing through a medium-sized or larger telescope you will be treated to one of the best views of the planet's famous ring system, as well as some of its larger moons.



*August*
## Boe-CFT launch


The Boeing Crew Flight Test (Boe-CFT) will depend on the success of the uncrewed mission in March, but should all go well NASA astronauts Eric Boe, Christopher Ferguson and Nicole Aunapu Mann will be heading for the ISS in the first manned test of the craft. Planned to launch on an Atlas V rocket from Cape Canaveral, Florida, the craft will spend eight days docked to the ISS. This and SpaceX's Dragon test will be a milestone in space exploration, opening up the possibilities of commercial spaceflight.

*11 November*
## Mercury transit across the Sun

The passage of a planet across the Sun is a rare event to witness. A telescope equipped with a solar filter will be required to watch this transit safely, with a magnification of at least 50x recommended for a good view of Mercury making its way around the Sun, which is 277-times bigger than its closest planet.

The transit will start at sunrise across North America, with the entire transit visible from the East Coast, South America and west Africa. The transit will be visible from the whole of Africa, Europe and Scandinavia as the Sun sets. Mercury will not make another visible transit until November 2032, so make sure you take this chance!

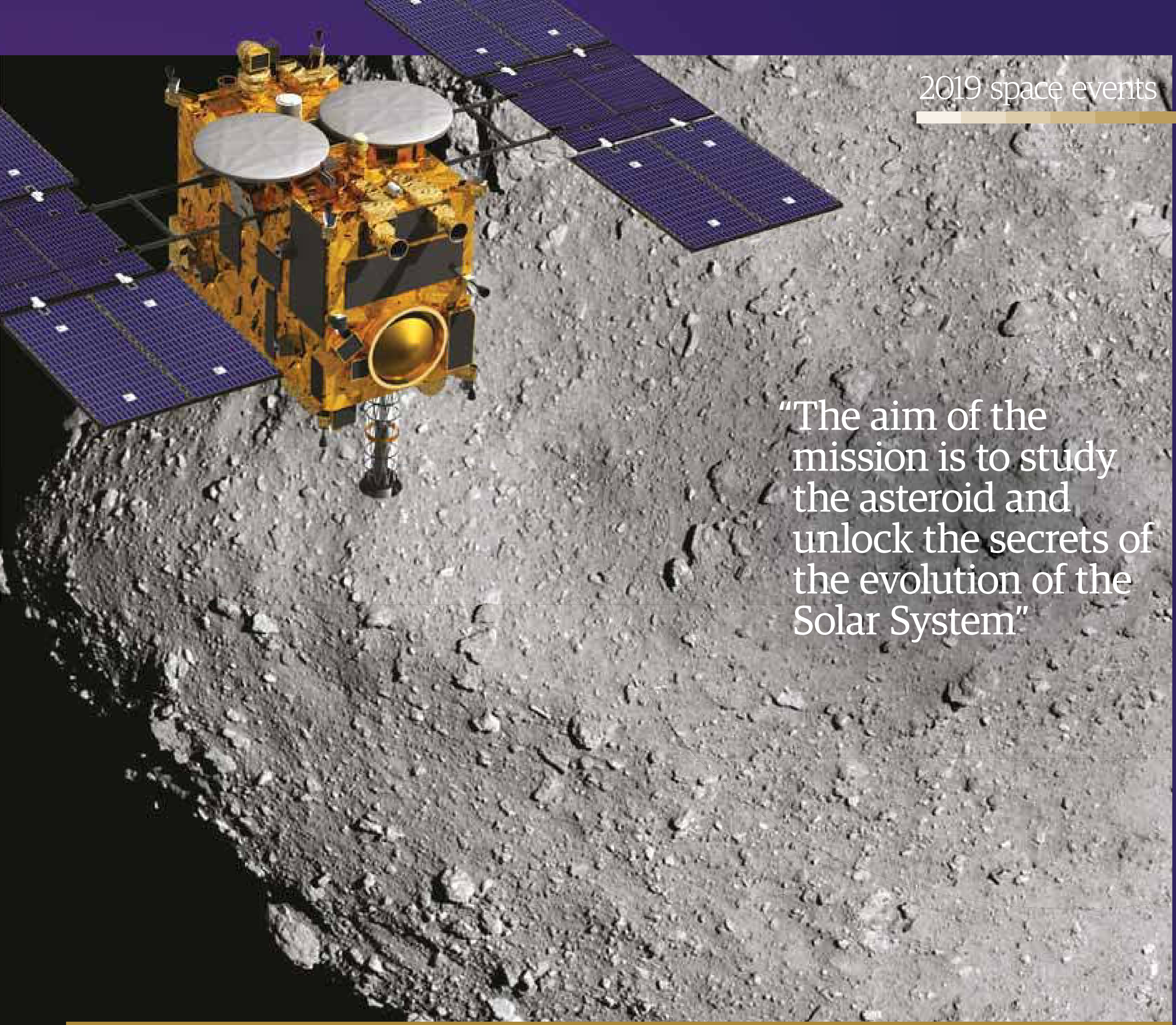
*Late 2019*
## Chang'e 5 sample-return mission to the Moon

Postponed due to failures with China's Long March 5 launch vehicle in 2017, Chang'e 5 will be the first lunar sample-return mission since the former Soviet Union's Luna 24 back in 1976 and aims to bring back at least two kilograms (4.4 pounds) of Moon rock. The region selected for this sample collection is Mons Rümker, a volcanic formation in the Ocean of Storms in the northwest of the Moon's nearside.

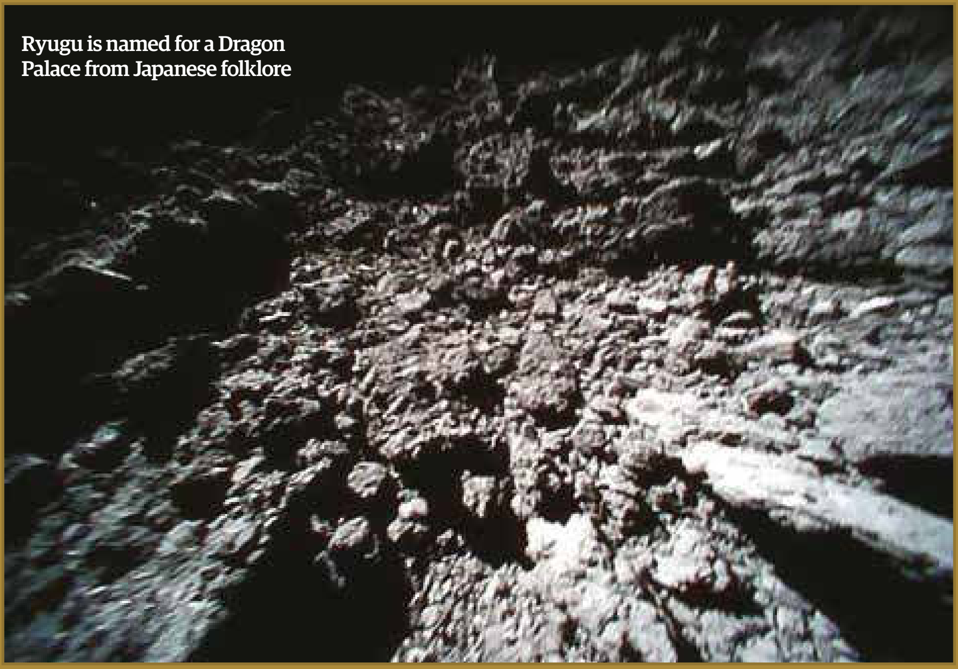
China has previously proven it is capable of performing a lunar landing, having had success with 2013's Chang'e 3 lander and Yutu rover, cementing the country's place as a growing power in space exploration.


Chang'e 5 aims to bring Moon rock back for research


You can follow Mercury's path across the Sun, visible as a small, dark dot



“The aim of the mission is to study the asteroid and unlock the secrets of the evolution of the Solar System”



Ryugu is named for a Dragon Palace from Japanese folklore

*December*

## Hayabusa2 heads home

The successor to the Japan Aerospace Exploration Agency's (JAXA) Hayabusa sample-return mission, Hayabusa2's target was a carbonaceous – or C-type – asteroid, 162173 Ryugu. Launched on 3 December 2014, the aim of the mission is to study the asteroid and unlock the secrets of the evolution of the Solar System, since asteroids are thought to have delivered water – and therefore life – in the Solar System's early history.

At the time of writing, Hayabusa2 has successfully deployed two rovers onto the surface which have returned fascinating images and data about this barren, icy space rock, and is preparing to collect three samples for return. In December 2019, Hayabusa2 will begin its homecoming with the precious cargo on board, eventually dropping it off for further study on Earth.

*26 December*

## Annular solar eclipse

A solar eclipse is only possible because the apparent size of the Sun and Moon are the same in the sky when viewed from Earth. Also known as a 'ring of fire', an annular solar eclipse occurs when the Moon is too far away from Earth - due to its elliptical orbit - to block the entirety of the Sun's light. Although you can't see the corona this way, the ring of sunlight around the dark Moon looks astonishing in itself. The path of the eclipse will start in Saudi Arabia, travelling east across south India, north Sri Lanka and Indonesia. A partial eclipse will also be visible throughout most of Asia and north Australia.

**The Sun's light creates a golden ring from behind the Moon**

"An annular solar eclipse occurs when the Moon is too far away from Earth to block the entirety of the Sun's light"

*22 December*

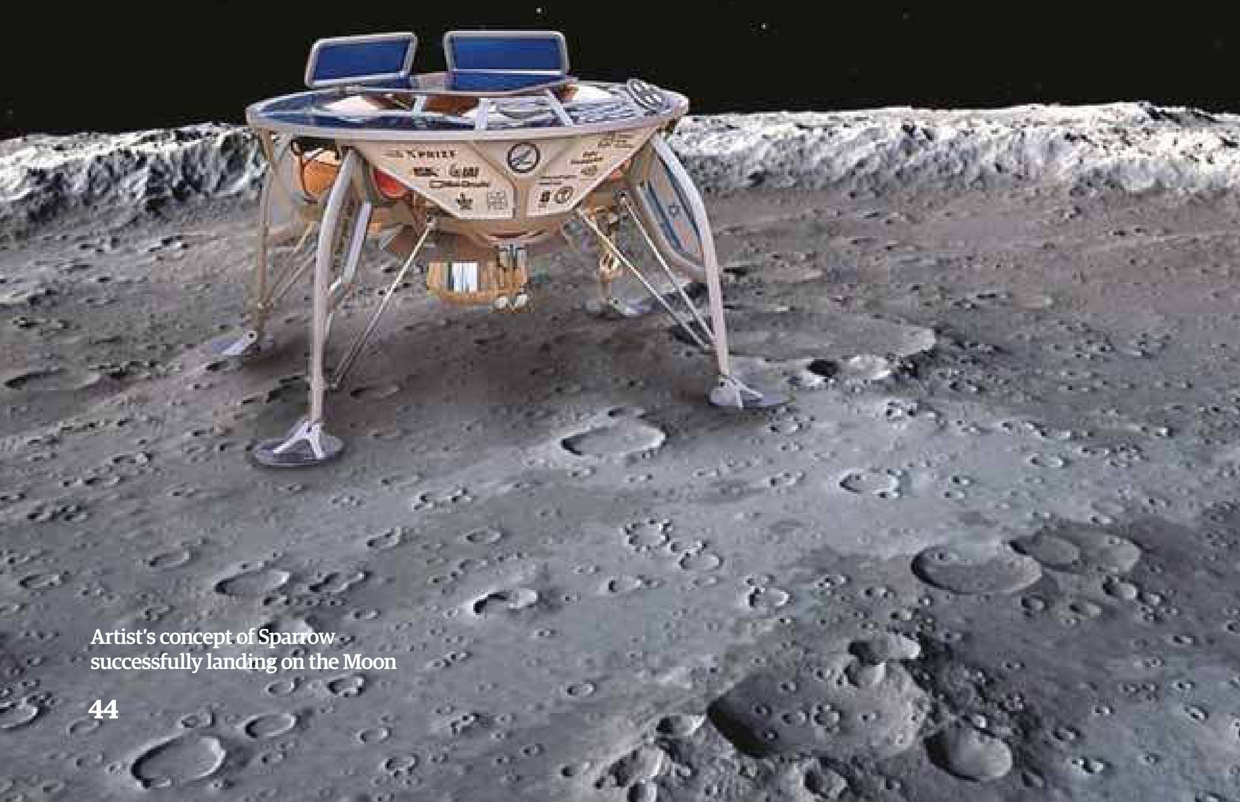
**Winter solstice**

The winter solstice provides the most hours of darkness in a day, perfect for a long stargazing session!

*2019*

## SpaceIL's Sparrow to launch

Originally conceived as part of the unclaimed Google Lunar X Prize, SpaceIL, an Israeli non-profit organisation funded in part by the Israeli Space Agency (ISL), still plans to launch its entry this year in the form of its Sparrow spacecraft. Planned to launch on a SpaceX Falcon 9 from Cape Canaveral in Florida, Sparrow aims to be captured in lunar orbit before attempting a soft landing on the surface in a two-day operation. Instruments on the 585-kilogram (1,300-pound) Sparrow craft include a magnetometer developed by the Weizmann Institute of Science.



Artist's concept of Sparrow successfully landing on the Moon

### Meteor showers

Some showers don't produce as many meteors per hour as others, but spotting a shooting star is always a great experience.

**Quadrantids**
**Dates:** 1 to 12 January
**Peak:** 4 January
**Max per hour:** 80
**Constellation:** Boötes

**Lyrids**
**Dates:** 14 to 30 April
**Peak:** 23 April
**Max per hour:** 20
**Constellation:** Lyra

**Eta Aquarids**
**Dates:** 19 April to 28 May
**Peak:** 6 May
**Max per hour:** 20
**Constellation:** Aquarius

**Delta Aquarids**
**Dates:** 12 July to 23 August
**Peak:** 30 July
**Max per hour:** 20
**Constellation:** Aquarius

**Perseids**
**Dates:** 14 July to 24 August
**Peak:** 13 August
**Max per hour:** 100
**Constellation:** Perseus

**Draconids**
**Dates:** 6 to 10 October
**Peak:** 9 October
**Max per hour:** 10
**Constellation:** Draco

**Orionids**
**Dates:** 2 Oct to 7 Nov
**Peak:** 22 October
**Max per hour:** 15
**Constellation:** Orion

**Taurids**
**Dates:** 20 Oct to 10 Dec
**Peak:** 13 November
**Max per hour:** 5
**Constellation:** Taurus

**Leonids**
**Dates:** 6 to 30 November
**Peak:** 18 November
**Max per hour:** 15
**Constellation:** Leo

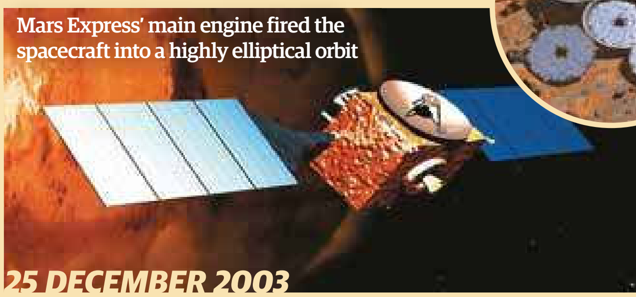
**Geminids**
**Dates:** 4 to 17 December
**Peak:** 14 December
**Max per hour:** 120
**Constellation:** Gemini

**Ursids**
**Dates:** 17 to 25 December
**Peak:** 23 December
**Max per hour:** 10
**Constellation:** Ursa Minor

# *Celebrating* 15 YEARS OF MARS EXPRESS

**All About Space** marks an important milestone in the life of one of the European Space Agency's most successful spacecraft

— Written by Lee Cavendish —



Mars Express' main engine fired the spacecraft into a highly elliptical orbit

25 DECEMBER 2003

## Arrival of Mars Express and Beagle 2

Mars Express is equipped with a sophisticated instrument suite fitted with surface/subsurface, atmosphere and plasma instruments able to reveal remarkable details about Mars. This culmination of years of ideas, construction and travelling through space all relied on Mars Express entering a safe orbit around Mars.

Launched with Mars Express was the first British-built Martian lander, Beagle 2. The lander was released from Mars Express on 19 December, six days before the mother craft entered orbit around Mars, and scientists hoped that it would uncover important clues as to Mars' ancient astrobiology. Unfortunately, contact with Beagle 2 was never made after its scheduled touchdown date and ESA declared it lost in February 2004.

30 MARCH 2004

## The mysterious methane signal

Mars Express' Planetary Fourier Spectrometer (PFS) instrument picked up an unusual signal while analysing the atmosphere. The expected atmospheric candidates were seen – such as carbon monoxide and water vapour – but this unusual signal was later interpreted as being methane.

This was an exciting discovery, as methane can only survive in the atmosphere for a few hundred years. This begs the question, is there some recent volcanic activity or biological process that is replenishing the atmosphere?

Elysium Planum was one of the regions where tiny amounts of methane were detected

2004

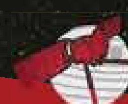
17 MARCH 2004

## Water ice found at the south pole

It was previously known that Mars has ice situated at its poles. This is not to the same extent as Earth, as Mars' polar ice is much thinner and more seasonally variable. More surprising, Mars Express' Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité (OMEGA) instrument revealed that water ice, as well as carbon dioxide ice, is present at both the north and south poles.

OMEGA measured the amount of sunlight and heat reflected from the poles to confirm this result. In the case of the south pole, scientists were also surprised to see vast amounts of perennial water ice encasing it.

The steep slopes, known as 'scarps', are made almost entirely of water ice



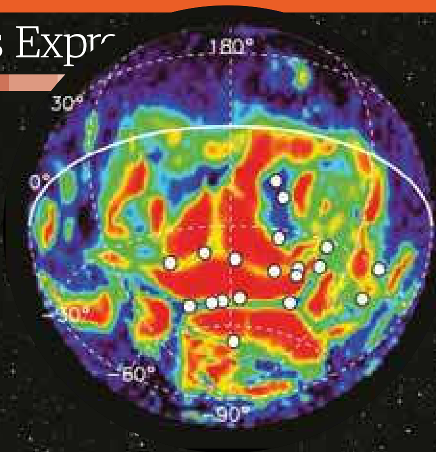
### Mission Objectives

1 Provide a global, 3D, high-resolution photogeologic analysis to discover more about the surface and geology of Mars.

2 Study the subsurface structure of Mars by using radar beams. The different materials or structures sent back radar echoes, allowing scientists to produce an accurate 3D survey.

3 Construct an accurate picture of the Martian meteorology and climate by determining the atmospheric circulation and composition.

4 Study the interaction between the Red Planet's atmosphere and outer space




11 AUGUST 2004

## Aurorae scattered over Mars

Aurorae usually occur when charged particles from the solar wind collide with a planet's atmosphere at the poles due to the nature of the planet's magnetic field. When Mars Express first detected localised aurorae on Mars via the Spectroscopy for the Investigation of Characteristics of the Atmosphere of Mars (SPICAM) instrument, it cast a new light.

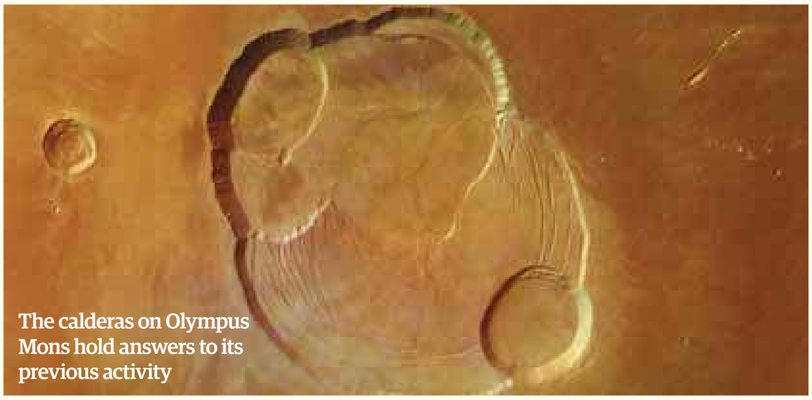
Along with NASA's Mars Global Surveyor, scientists deduced that the Martian crust produces cusp-like magnetic structures capable of concentrating the excited particles in very small regions.

23 DECEMBER 2004

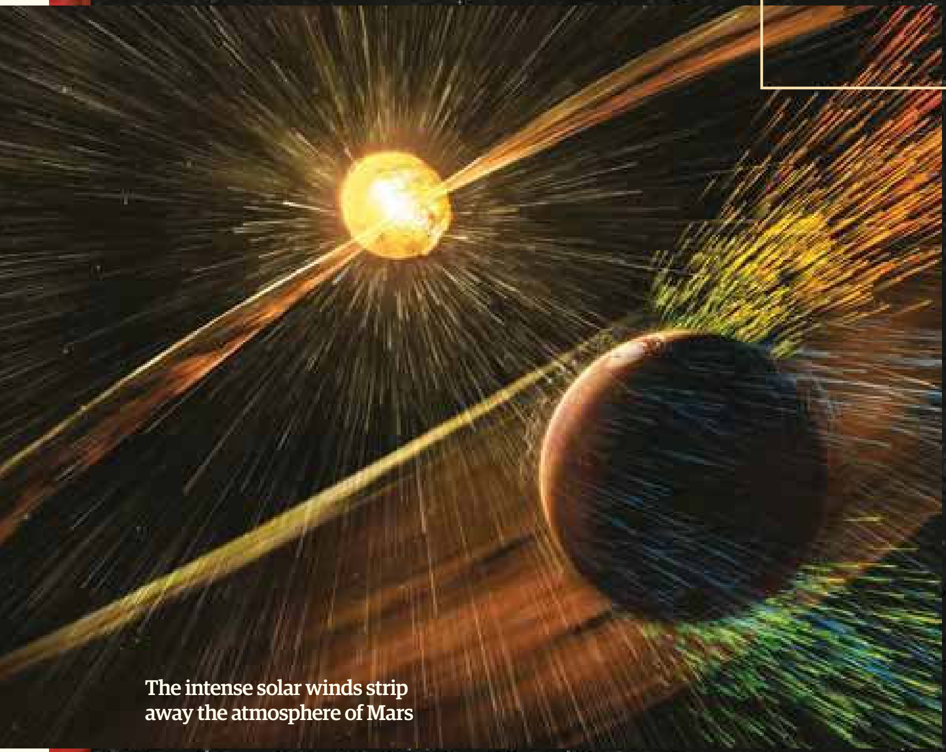
## The Red Planet's eruptive past

Mars is famous for having the largest volcano in the entire Solar System. Olympus Mons is 25-kilometres (15-miles) high – almost three-times taller than Mount Everest. The High Resolution Stereo Camera (HRSC) on Mars Express showed that the most massive volcanoes, including Olympus Mons, were active more recently than thought.

The analysis of Olympus Mons. along with four other major volcanoes Arsia Mons, Ascraeus Mons, Albor Tholus and Hecates Tholus show that volcanic activity could have occurred as recently as two million years ago. Scientists previously thought such activity on Mars ceased around half a billion years ago. This, along with data suggesting that the activity was also very sporadic, meant scientists had to rethink the interior and evolution of Mars based on these results.


The calderas on Olympus Mons hold answers to its previous activity

2005


The intense solar winds strip away the atmosphere of Mars

27 SEPTEMBER 2004

## The depleting atmosphere

Mars was once a planet with water flowing across the surface and had a suitable atmosphere that kept it relatively warm, which could have supported life. Today, Mars is a cold, dry planet with an atmosphere 150-times lower in pressure than on Earth, so Mars Express set out to find out what happened during its evolution to transform the planet.

Mars Express' Analyser of Space Plasma and Energetic Atoms (ASPERA) instrument took valuable data about the interaction between the solar wind and the upper atmosphere and ionosphere. Data showed that in just a few minutes the upper atmosphere can alter and open a path for the solar wind to penetrate deeper into the atmosphere, interacting with water ions and causing them to escape into space.

However, this ion escape rate depends on varying solar winds and cannot fully account for the drastic depletion over the last 3.5 billion years. This means another mechanism must have been at work, possibly removing neutral atoms in the upper atmosphere. A recent theory even suggests that dust storms play a part in kicking up atoms to higher altitudes where they then escape Mars.

30 NOVEMBER 2005

## The hidden, third layer in the ionosphere

Many exciting discoveries about the Martian surface came in the opening years of Mars Express, but this discovery confirmed the presence of a new, third layer in the ionosphere of the Martian atmosphere using its Mars Radio Science Experiment (MaRS).

Situated at an altitude between 65 and 110 kilometres (37 and 68 miles), the MaRS instrument discovered regions of higher densities in charged particles such as electrons. The leading theory behind the origin of this layer is thought to be collisions between the ionosphere and meteorites.

"Many exciting discoveries about the Martian surface came in the opening years of Mars Express, but this discovery found a new, third layer in the ionosphere of the Martian atmosphere"

18 MARCH 2005

## Surveying former glaciers

As Mars Express swooped over the surface of Mars its High Resolution Stereo Camera (HRSC) found some intriguing traits in Mars' tropical and mid-latitude regions. Within these regions were features relating to recent and recurring glacial activity, known as debris aprons.

In a region called Promethei Terra, on the eastern rim of the Hellas Basin, there was an unusual 'hourglass'-shaped feature which caught the attention of many. Research found that it's an impact crater filled to the brim with ice and an assortment of small rocks. The lack of impact craters on the deposits indicates it's relatively young – another significant piece of evidence in determining the previous climate history of Mars.

Glaciers likely shaped the mid-latitude surface of Mars just a few million years ago


There are copious areas where hydrated minerals reside, shown here by green dots

30 NOVEMBER 2005

## Search for water boosted by locating hydrated minerals

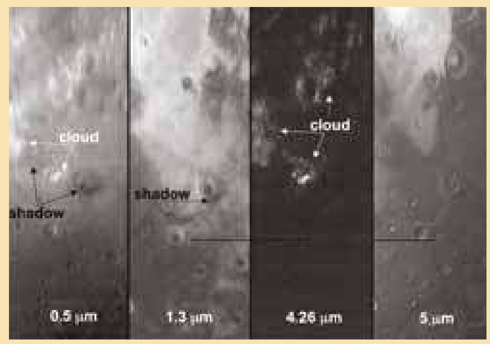
The first-ever detection of hydrated minerals on Mars caused worldwide excitement. During the last 15 years of observations OMEGA has recorded two classes of hydrated minerals, which are crystalline structures containing water. Phyllosilicates and hydrated sulphates were found over large areas, and although they are both a result of chemical alterations of rocks, they are formed in different ways. Phyllosilicates are formed from the reaction between igneous minerals and long-term exposure to water, whereas hydrated sulphates are formed from reactions with acidic water.

16 JANUARY 2008

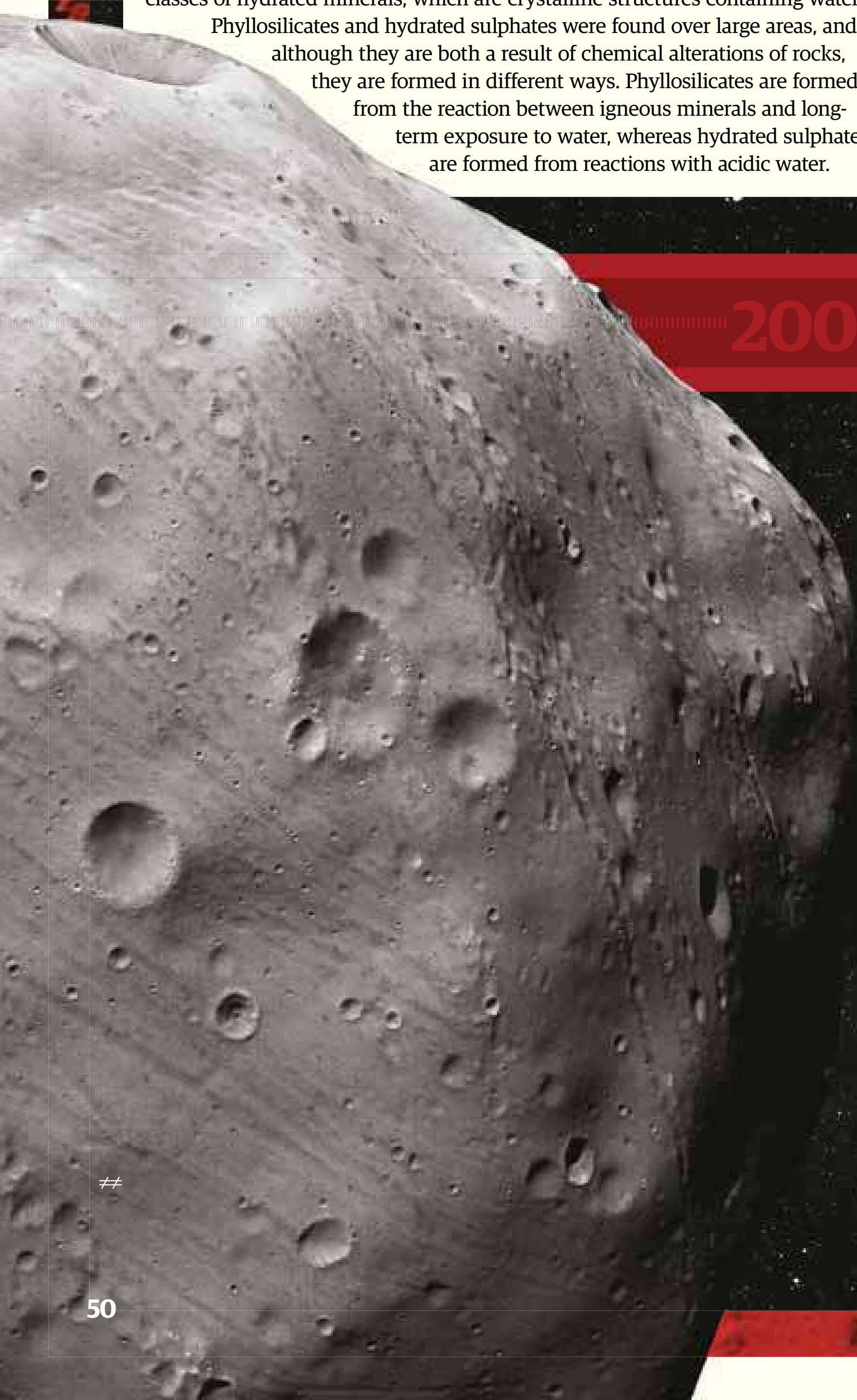
## Carbon dioxide ice clouds

Mars Express' OMEGA instrument detected carbon dioxide ($CO_2$) ice clouds, a unique feature of the Red Planet's climate. These clouds are formed from the freezing of carbon dioxide gas, which makes up 96 per cent of the Martian atmosphere.

These clouds were observed at wavelengths of 0.5 and 4.26 microns. This revealed that the abundance of clouds varies from Martian year to year - with one Martian year equating to 687 Earth days. In addition, these carbon dioxide clouds are large and dense enough to form shadows on the planet's surface, which suggests they are 80 kilometres (50 miles) above the surface.




2008 2009 2010



"The first-ever detection of hydrated minerals on Mars caused worldwide excitement"

3 MARCH 2010

## Phobos up-close

On this date Mars Express made its closest approach of Mars' largest moon, Phobos, flying just 67 kilometres (41 miles) above its surface. During this brief window of opportunity Mars Express was able to conduct a gravity experiment and produce some outstanding images.

Although it wasn't able to study Mars' other moon, Deimos, as closely, the information collected on Phobos was enough for astronomers to rethink its origins. Originally it was thought that these moons were captured asteroids. However, after density and mineral composition analysis, it is thought that these moons - and Phobos in particular - formed during a reaccretion of rocky material in Mars' orbit.

OCTOBER 2011 TO FEBRUARY 2012

# The Solid-State problem

For a period of several months, all operations and observations of the Mars Express spacecraft were halted due to an issue with its Solid-State Mass Memory (SSMM) system.

The SSMM is vital for storing the data collected by instruments prior to its transmission back to Earth, and the spacecraft entered safe mode as it failed to successfully read and write the data to memory modules. Fortunately, in the early months of 2012, the Mars Express team were able to create a new command system that meant the data could once again be completed, observations made and the data sent back to Earth. This led to the continuation of Mars Express with its original lifespan unaltered.

28 OCTOBER 2013

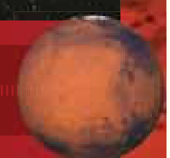
# The commemorative map celebrating a decade at Mars

2013 celebrated an impressive ten years of the Mars Express orbiter at Mars. This acknowledged Europe's first and finest space exploration mission and, as part of the achievement, a near-complete topographical map of the planet's surface was produced, which combined data from almost 12,500 orbits.

This map flaunts some remarkable sites on the Martian surface, courtesy of the HRSC instrument. These sights include Valles Marineris, Olympus Mons and other craters and mountains, as well as ancient river beds and lava flows.

Valles Marineris is a huge canyon that runs across Mars' equator

2011 2012 2013 2014 2015



16 JANUARY 2015

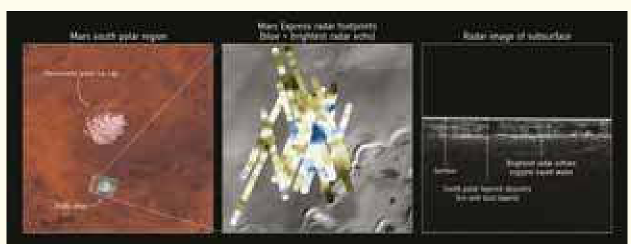
# Beagle 2 found

More than ten years after its disappearance, the long-lost Beagle 2 lander was found courtesy of NASA's Mars Reconnaissance Orbiter's (MRO).

"Not knowing what happened to Beagle 2 remained a nagging worry. Understanding now that Beagle 2 made it all the way down to the surface is excellent news," said Rudolf Schmidt, ESA's Mars Express project manager at the time. But if it landed successfully, where did it go wrong?

Images from the MRO's HiRISE (High Resolution Imaging Science Experiment) camera suggest that only three of its four solar panels were deployed. This couldn't supply enough power to allow the radio antenna to transmit data and communicate with Earth.


The slight reflective signal was deduced to be the missing Beagle 2




25 JULY 2018

# Hidden liquid water found at the south pole

Almost 15 years later Mars Express continues to get the scientific community excited - its most recent discovery found evidence for liquid water hidden under layers of ice and dust in the south pole.

The Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) instrument sent radar pulses towards the surface and measured the timing and strength of the returning pulses to determine that a body of water exists about 1.5 kilometres (one mile) below the south polar region's surface and is around 20 kilometres (12 miles) wide.

This sort of discovery doesn't only make astronomers think about Mars' ancient climate several billions of years ago, it raises tantalising thoughts to whether life could ever have existed here.

# ASK Space

*Our experts answer your questions*

HUNT FOR LIFE

## Could there be life on Europa?

Yes! Europa appears to have all of the ingredients that life requires: water, chemistry and energy. Europa's ocean is two- to three-times all of Earth's oceans combined, so liquid water abounds under its icy shell. Europa also appears to have chemical ingredients, seeded from the time that Jupiter and its moons formed or deposited periodically by comets and meteorites.

Volcanically active Io is also belching its guts out in the Jovian system, and Jupiter's massive magnetic field helps implant those sulphur-rich ions into the surface of Europa; if these or the other oxidised molecules made by radiation make it into the ocean, they might form a 'redox gradient'. This just means there might be a dearth of electrons at the top of Europa's ocean, and an abundance of electrons at the seafloor – generated by water-rock chemistry. Plenty of microorganisms on Earth take advantage of that imbalance to shuttle electrons around, getting some energy as payment. While not as efficient as energy from sunlight, plenty of microbial communities persist this way, usually in places where sunlight does not exist.

Add to that the possibility of geothermal energy at the seafloor, and even more complex communities could thrive – on Earth, these hydrothermal vents host octopuses, tubeworms and crabs! However, since the energy is not as abundant, life may not be either – it will be energy-limited, so we don't expect to see as much life in Europa's ocean as we have in ours.

**Dr Morgan Cable is a technologist for the Instrument Systems Implementation and Concepts Section at the NASA Jet Propulsion Laboratory in Pasadena, California.**

"Europa appears to have all the ingredients that life requires: water, chemistry and energy"

Europa is one of the most intriguing and highly anticipated targets for future exploration

SPACE EXPLORATION

# How does weightlessness affect the human body?

Transitioning from Earth's gravity to the lack of gravity in space and then back to Earth is tricky. Gravity affects almost all body systems, including the cardiovascular, the musculoskeletal, spatial orientation, balance and locomotion.

Astronauts often experience motion sickness and disorientation immediately upon entering space, but it resolves within a couple of days. After longer exposure to spaceflight your bones lose minerals and muscles atrophy.

NASA carefully monitors the astronauts aboard the ISS for such effects

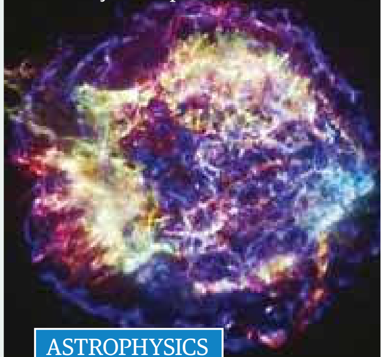
NASA makes sure that astronauts exercise daily and have proper nutrition during their missions to reduce the effects and to prepare them for landing back on Earth, and someday landing on Mars. Upon landing astronauts experience motion sickness again and often have trouble maintaining blood pressure since the cardiovascular system has detrained since living in microgravity is 'easy' compared to Earth for the heart and blood vessels.

NASA uses a rigorous reconditioning programme to ensure that they recover from the adaptation to spaceflight. One of the areas that NASA is concentrating on is how the fluids in the body shift upwards towards the head during spaceflight and the effect this shift has on the eyes and brain. While we do not completely understand the effect, we are exploring ways to alter it during spaceflight to maintain the health and wellbeing of the astronauts for current and future missions.

**Dr Jennifer Fogarty is the chief scientist for NASA's Human Research Program**

## Did you know?

Crew members aboard the International Space Station engage in physical exercise for two-and-a-half hours a day, six times a week while in orbit.



An abundance of different elements are jettisoned into space courtesy of a supernova

ASTROPHYSICS

# Would it be possible to ride a supernova wave?

Supernovae are the explosions of stars. Only certain types of stars explode – not to worry, our Sun isn't one of them – and when they do they shine as bright as 100 billion Suns and throw out material at thousands of kilometres per second. That would be quite the surf to ride!

For most supernovae – those which are the explosions of massive stars – that material that is flying out is made up of the elements that the star produced during its life: helium, calcium, oxygen, carbon and so on up to iron. Even heavier elements are made in the explosion itself.

In fact, such supernovae are the only places we know in the universe where these elements are created and released into space. This means that every calcium atom in our bones, every oxygen atom we breath, every iron atom in our blood – all were part of a supernova, sometime, somewhere, and made their way to our bodies through the material that gathered to make the Sun, the Earth and eventually us. In that sense we are all made of particles that rode a supernova wave at some point in their past!

**Dr Iair Arcavi is an Einstein fellow at the Department of Physics, University of California, Santa Barbara, California.**

MOONS

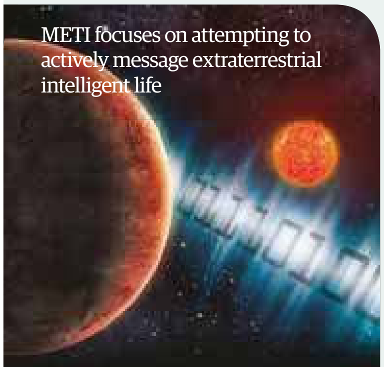
# What is powering the volcanoes on Jupiter's moon Io?

The energy source that powers Io's volcanoes lies in the tides exerted by Jupiter and in the slightly elliptical orbit of the satellite. When the Voyager 1 spacecraft approached Io in March 1979 the images sent back to Earth revealed that its surface appeared dotted with a multitude of volcanic centres, of which a dozen exhibited full activity with towering lava flows and plumes up to some hundred kilometres high.

Under normal conditions the intense tidal forces produced by Jupiter would eventually reset the eccentricity of Io's orbit in a short time, making it a perfect circumference. However, the nearby satellite Europa has an orbital period exactly twice that of Io. This 1:2 resonance forces Io's orbit to be slightly elliptical over time and leads the two satellites to renew their mutual position every 3.55 days – less important is another 1:4 synchronism with the orbital period of Jupiter's moon Ganymede. As a consequence the Jupiter tide causes a periodic deformation of the entire satellite which heats and melts its interior, producing intense volcanic phenomena on the surface to such an extent that Io holds the record of 'most volcanically active body of our Solar System'.

**Dr Federico Tosi is a Staff Research Scientist at the Institute for Space Astrophysics and Planetology – National Institute for Astrophysics.**

Io is the closest of the Galilean moons to Jupiter



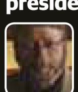
METI focuses on attempting to actively message extraterrestrial intelligent life

HUNT FOR LIFE

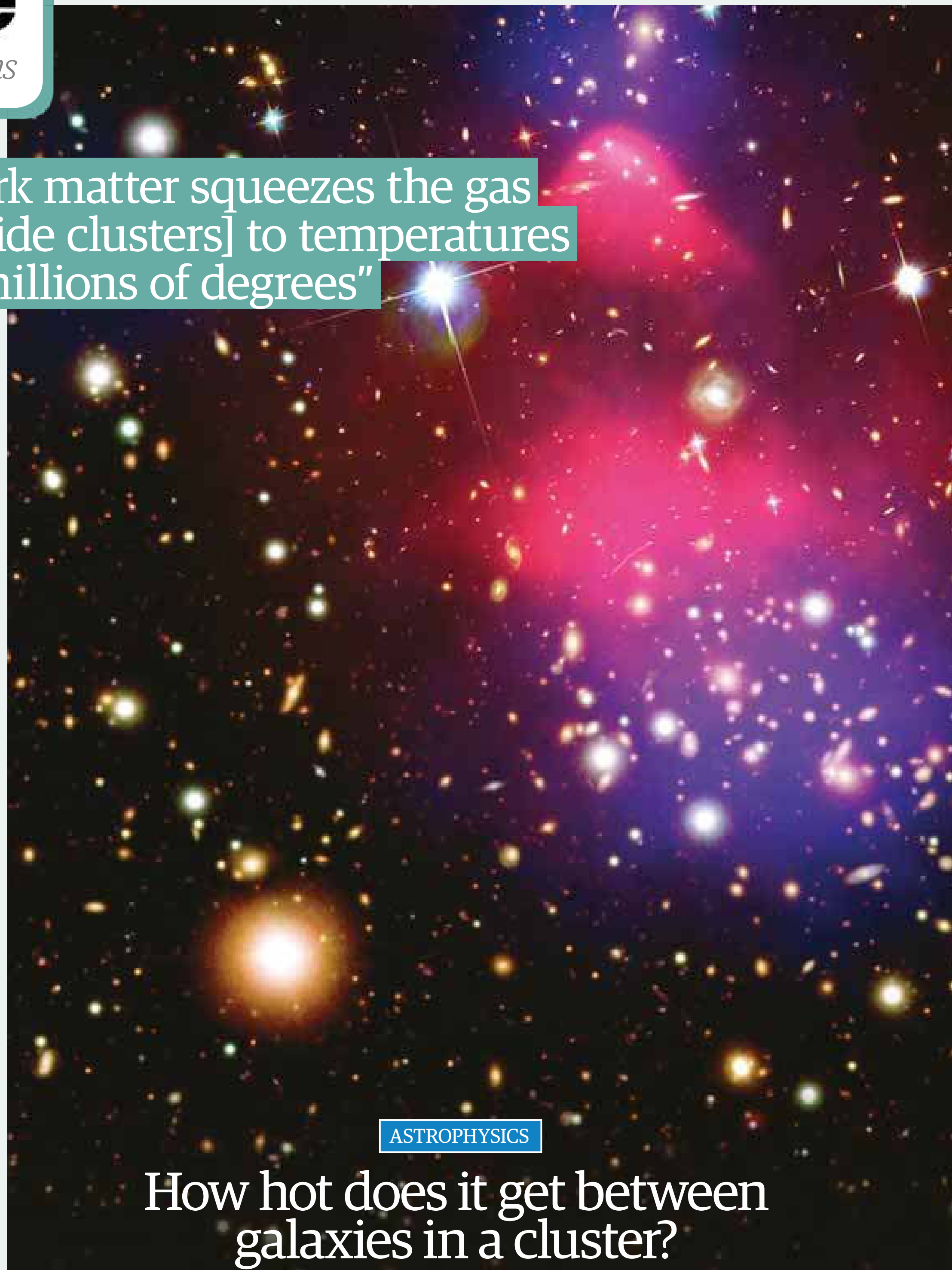
## Could there be a civilisation more advanced than Earth's?

If we make contact they're guaranteed to be more advanced than us. If they're less advanced they won't have the technology to communicate across interstellar distances. We've had radio technology for less than a century. If that's typical of civilisations in our galaxy – that they survive for only a century and then destroy themselves or simply stop exploring – then we won't both exist at the same time, given the 13-billion-year age of the universe. We'll only make contact if the aliens have been around much longer than us, meaning they'll be more advanced.

But couldn't they have our level of technology, but just be much longer-lived? Maybe that's the key to sustainability of civilisations on cosmic time scales – relying on primitive technology that uses minimal resources. That's certainly conceivable, but even then, the extraterrestrial society would have a stability that far surpasses Earth's cultural chaos. Even if the aliens we contact aren't technologically advanced, they'll be much more socially advanced.



**Dr Douglas Vakoch is the president of Messaging Extraterrestrial Intelligence, based in San Francisco**



"Dark matter squeezes the gas [inside clusters] to temperatures of millions of degrees"

ASTROPHYSICS

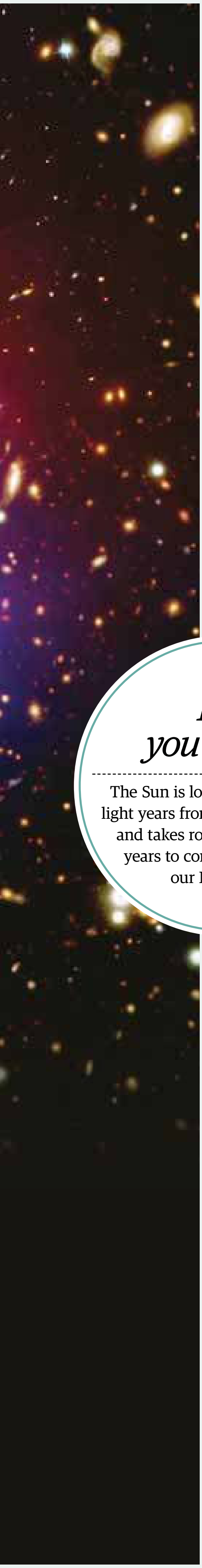
## How hot does it get between galaxies in a cluster?

Many galaxies in the universe live alongside others, tethered to each other by their mutual gravity to form giant clusters; the largest gravitationally bound structures in the universe. The galaxies in a cluster are only a tiny fraction of the total matter present – there's up to ten-times as much mass in the form of a hot tenuous atmosphere filling the space between the galaxies, known as the intracluster medium.

The enormous gravitational field of the whole cluster – particularly that of the dominant, but unobservable dark matter – squeezes this gas to heat it to extraordinarily high temperatures of millions of degrees. There is so much energy in this gas that the electrons are no longer bound to their atomic nucleus, but instead form a plasma composed completely of electrically charged particles. Too hot to be seen in optical images, this plasma is only observable in the X-ray waveband where it appears as a giant, smooth puddle centred on the most massive galaxy in the cluster.

The temperature of the intracluster medium is a puzzle – it radiates so much energy through its X-ray emission that it should have long since cooled down. The fact that it remains so hot requires a continual heating mechanism within the cluster, most likely related to the mechanical energy of sound waves travelling through the cluster gas. These waves in turn originate from disturbances caused by the active supermassive black hole found at the core of the central and most massive galaxy.

**Dr Carolin Crawford is a public astronomer at the Institute of Astronomy, University of Cambridge.**



SPACE EXPLORATION

## What's it like training for a mission to space?

From my experience, training for a six-month mission to space is very involved these days, namely because there are a lot of elements to it. We've got to get [into space] and we've got to be able to get back safely, so that means we [the crew] have to know everything about the spacecraft we are flying. For us, that is the Russian Soyuz spacecraft.

Training as a crew of three – with myself; Tim Kopra, my NASA crewmate, and Yuri Malenchenko, my Russian commander of the Soyuz – has taken a lot of time and commitment, but then we have also had to get to know everything about the space station where we will be living, and that includes knowing about the various different modules – the Russian segment, the American laboratories, the European laboratories, the Japanese laboratories and the various other modules that we will be using up there.

We also have to know how to maintain the space station and keep it running safely, and we need to be able to do certain tasks such as robotic operations, which involves using the Canadian robotic arm to grab visiting vehicles and dock them to the Space Station – that's how we keep the ISS supplied. That is a big task that astronauts have to be able to do, as well as the possibility of doing spacewalks in order to complete any maintenance outside of the ISS.

**Major Tim Peake is an European Space Agency astronaut**

Tim Peake undertakes a spacewalk from the ISS

### *Did you know?*

The Sun is located some 28,000 light years from the galactic centre and takes roughly 230 million years to complete one lap of our Milky Way.

ASTROPHYSICS

## What determines the strength of a magnetic field?

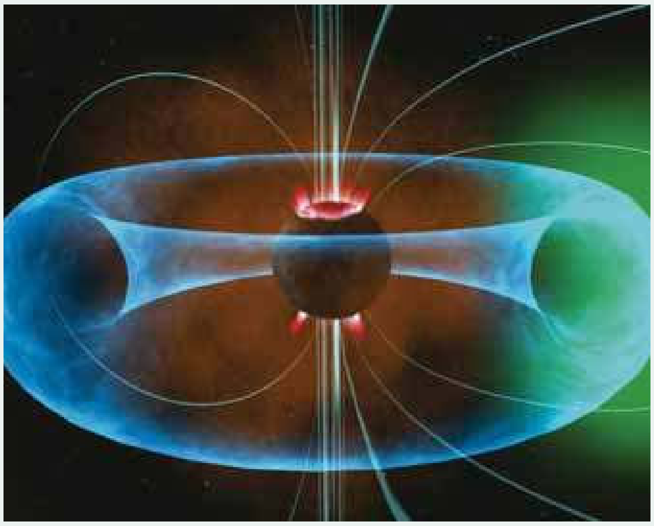
It has been almost a century since Sir Joseph Larmor broached his celebrated question: "How could a rotating body such as the Sun, or Earth, become a magnet?" Although a predictive unified theory is still lacking, we believe that vigorous motions of electrically conducting fluids generate the magnetic field via the dynamo action which, in essence, converts kinetic energy into magnetic one.

Two competing frameworks attempt to explain the strength of the magnetic field in planetary bodies. The first assumes that the balance of forces acting on this electric-conducting region, such as those arising from buoyancy or rotation, sets the field's strength. In this framework the planetary rotation rate, as well as the properties of the conducting fluid – in other words how good of a conductor it is – are key aspects required to predict the magnitude of the dynamo, as well as its structure.

The other framework assumes that above a certain planetary rotation the energy balance in the planets' or stellar interior is the main consideration in determining the field strength. Limited by few sample points in our own Solar System, it is not clear which theory offers a more accurate description of the dynamo strength. New observations of exoplanets' radio emissions, a good proxy of their magnetic fields, should provide very valuable constraints to this question.

**Dr Mohamed Zaghoo is a research associate at the Laboratory for Laser Energetics, a facility at the University of Rochester**

A strong magnetic field can help protect the star or planet from harmful cosmic rays



© NASA; Danielle Futselaar/METI

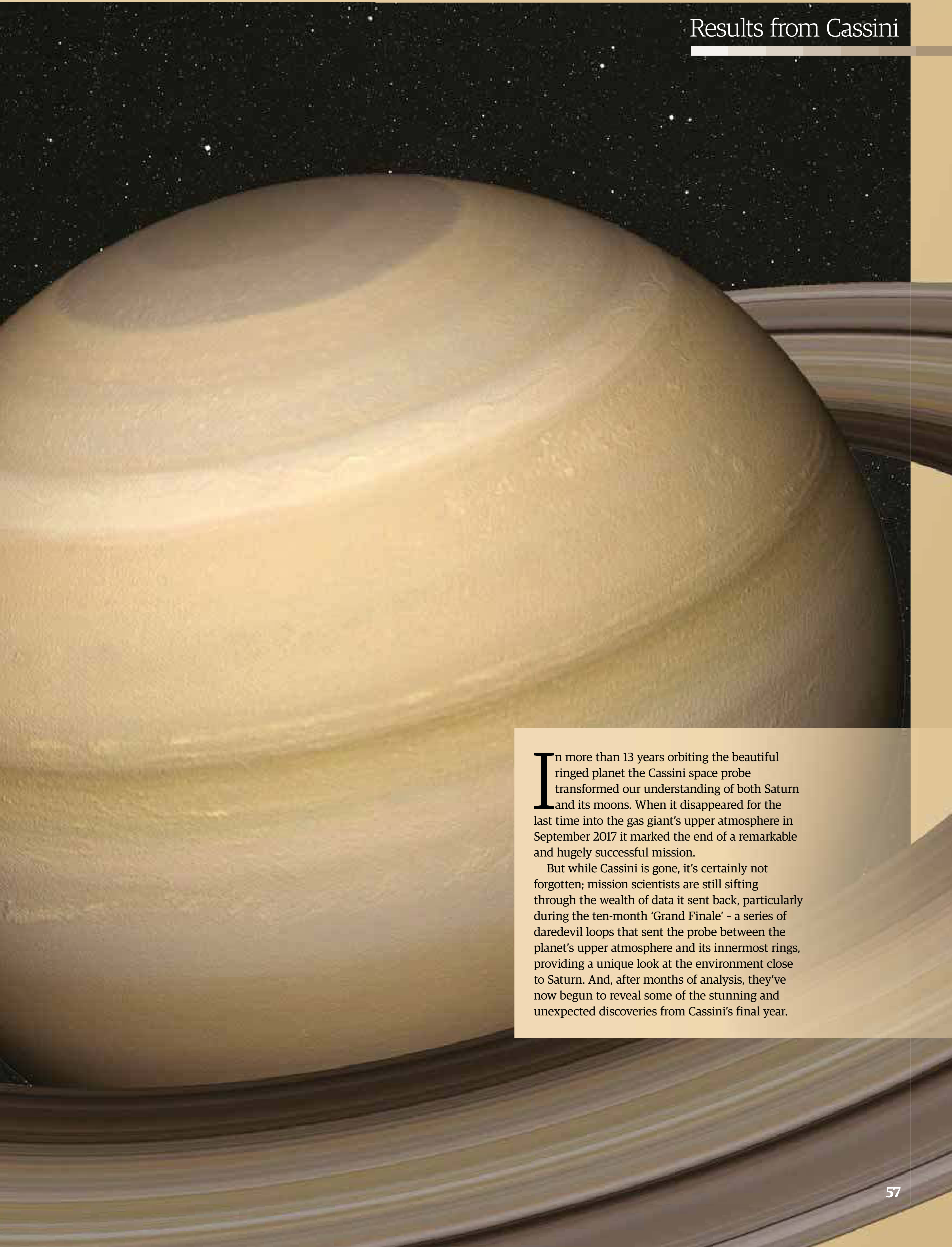
*GRAND FINALE: THE RESULTS*

# BRAND NEW DISCOVERIES AT SATURN

Cassini may have plunged to destruction, but scientists are continuing to unravel some surprising findings from its final days

— Reported by Giles Sparrow —

© Dimitar Todorov / Alamy Stock Photo; Adrian Mann

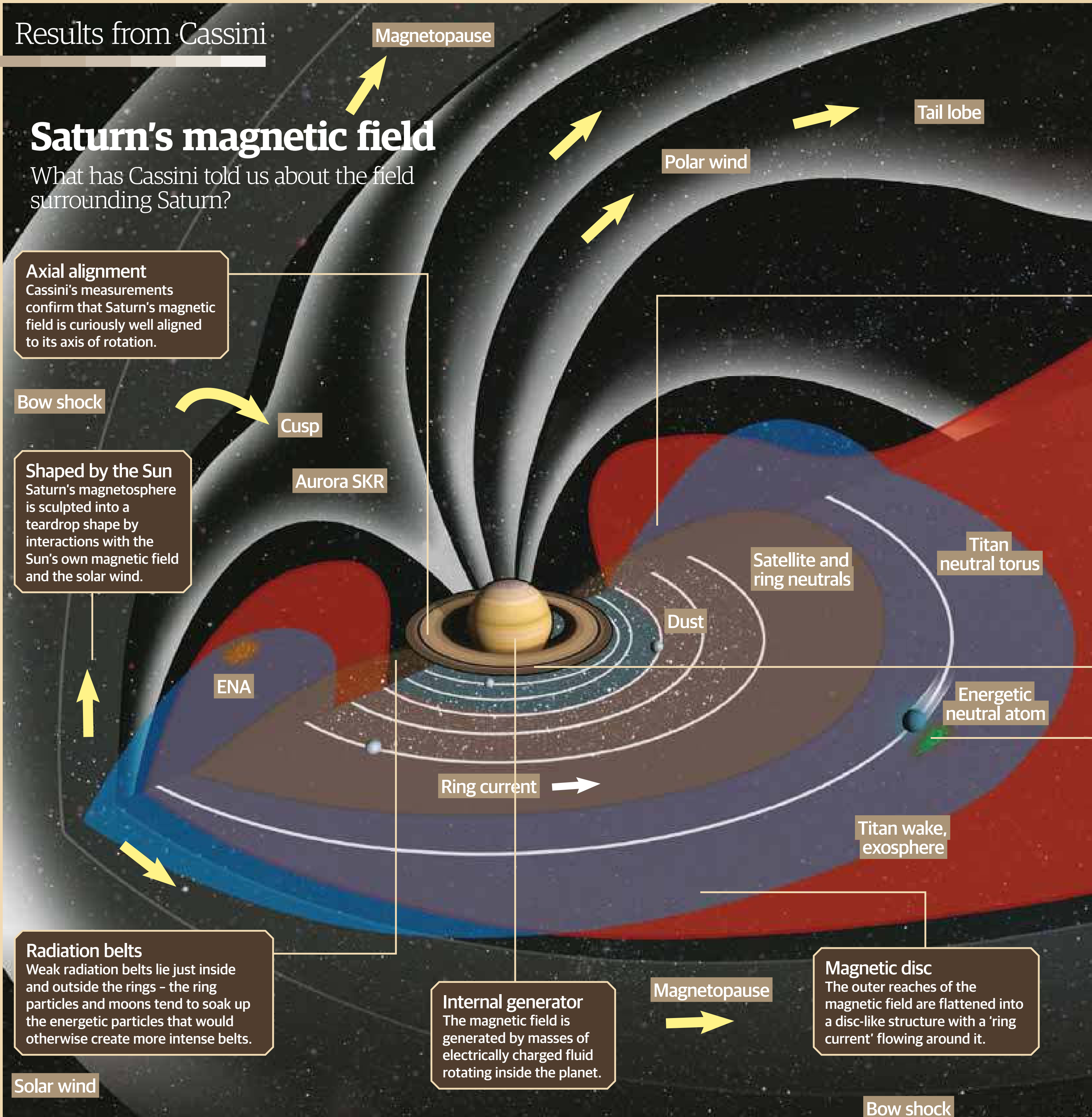


In more than 13 years orbiting the beautiful ringed planet the Cassini space probe transformed our understanding of both Saturn and its moons. When it disappeared for the last time into the gas giant's upper atmosphere in September 2017 it marked the end of a remarkable and hugely successful mission.

But while Cassini is gone, it's certainly not forgotten; mission scientists are still sifting through the wealth of data it sent back, particularly during the ten-month 'Grand Finale' – a series of daredevil loops that sent the probe between the planet's upper atmosphere and its innermost rings, providing a unique look at the environment close to Saturn. And, after months of analysis, they've now begun to reveal some of the stunning and unexpected discoveries from Cassini's final year.

# Saturn's magnetic field

What has Cassini told us about the field surrounding Saturn?




**Axial alignment**
Cassini's measurements confirm that Saturn's magnetic field is curiously well aligned to its axis of rotation.

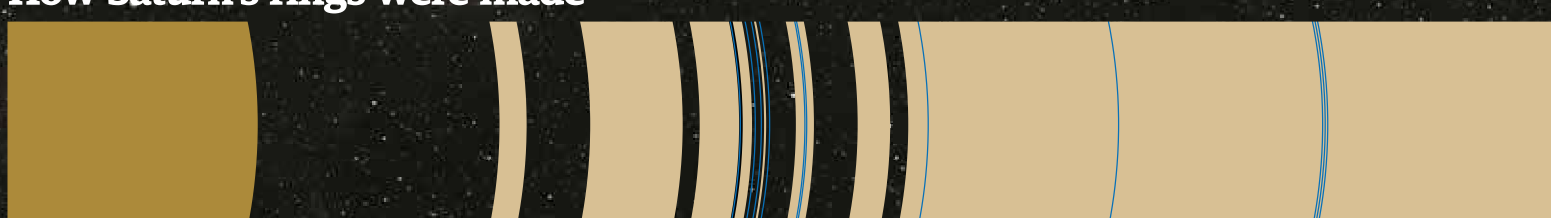
**Shaped by the Sun**
Saturn's magnetosphere is sculpted into a teardrop shape by interactions with the Sun's own magnetic field and the solar wind.

**Radiation belts**
Weak radiation belts lie just inside and outside the rings – the ring particles and moons tend to soak up the energetic particles that would otherwise create more intense belts.

**Internal generator**
The magnetic field is generated by masses of electrically charged fluid rotating inside the planet.

**Magnetic disc**
The outer reaches of the magnetic field are flattened into a disc-like structure with a 'ring current' flowing around it.

## How Saturn's rings were made

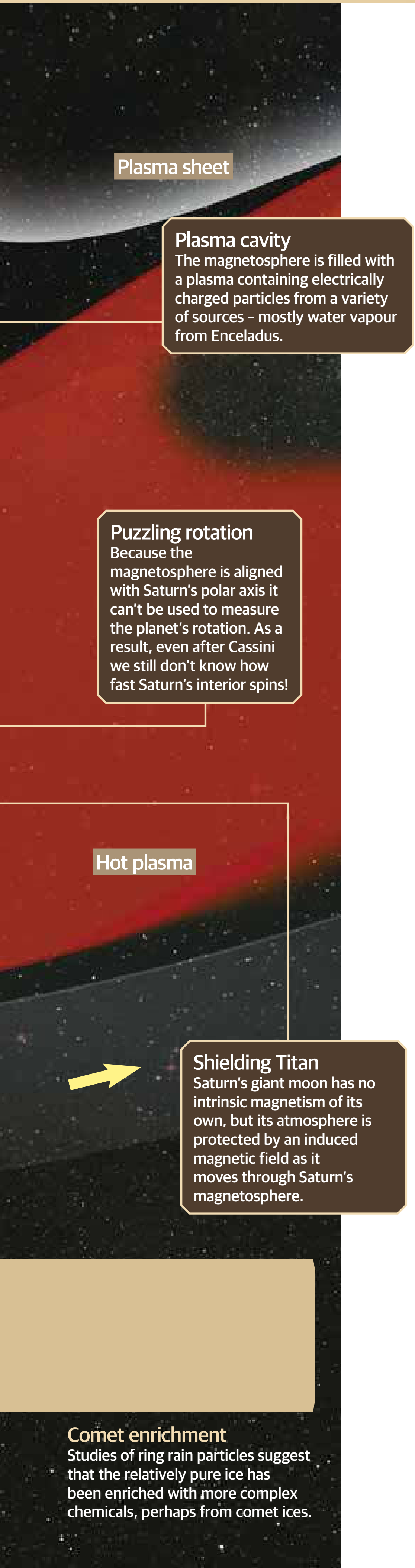


**Idea 1: Shattered moonlets**
One theory is that the rings formed when comet impacts broke up one or more small moonlets orbiting inside Saturn's Roche limit.

**Idea 2: Lunar break-up**
Alternatively, a larger moon may have been pushed inside the Roche limit where tidal forces eventually tore it apart.

**Varied rings**
Over a long period, collisions and tidal forces spread the debris evenly around the planet and began to draw smaller particles closer to the planet.

**Tidal gaps**
Gaps in the rings developed where orbiting particles would experience regular tidal pulls from more distant orbiting moons.



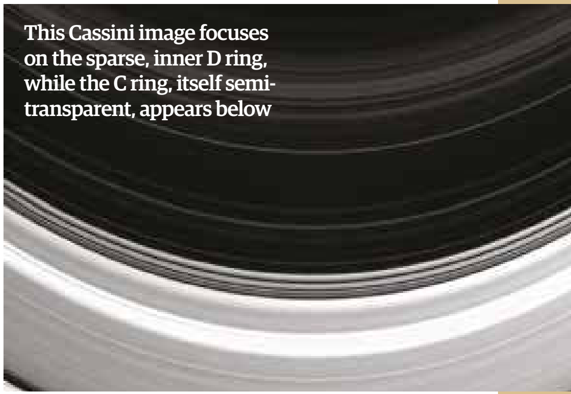

Cassini's Grand Finale was carefully planned from the outset. "The spacecraft had already gone way beyond its expected lifetime and through two extended missions, but it was running out of fuel, and we couldn't just leave it to wander through the Saturn system," explains Dr Hunter Waite of the Southwest Research Institute in San Antonio, Texas. "The risk of contaminating Titan or Enceladus if the spacecraft hit them was too large to ignore. We had to come up with a deterministic way to destroy the spacecraft, so we used Titan's gravity to steer Cassini in between the rings on an elliptical path."

Cassini's orbit had been carefully managed to reduce the risk of a catastrophic encounter with one of the countless ring particles in orbit around Saturn. With the rings confined to a narrow plane above Saturn's equator the spacecraft's orbit was sharply tilted or inclined, ensuring that it would cross the dangerous ring plane only briefly.

"Travelling at speeds of up to 37 kilometres per second [23 miles per second] relative to the planet, even a BB-sized object [a small pellet] can take out a spacecraft," says Waite, "so, just like everything we did, it was carefully orchestrated and verified using all the data we had to confirm the region we were sending the spacecraft through was dust-free enough that it wouldn't cause us a problem and potentially destroy the spacecraft prematurely. Fortunately that proved right: we orbited 22 times and then after we bumped it slightly with another close approach to Titan, Cassini was gone. When it got into the upper atmosphere it didn't take long to just tumble and burn up."

Hunter Waite is principal investigator for one of Cassini's key science tools, the Ion and Neutral Mass Spectrometer (INMS), and the data his instrument collected during its final months of operation is already changing ideas about the structure and evolution of Saturn's rings.

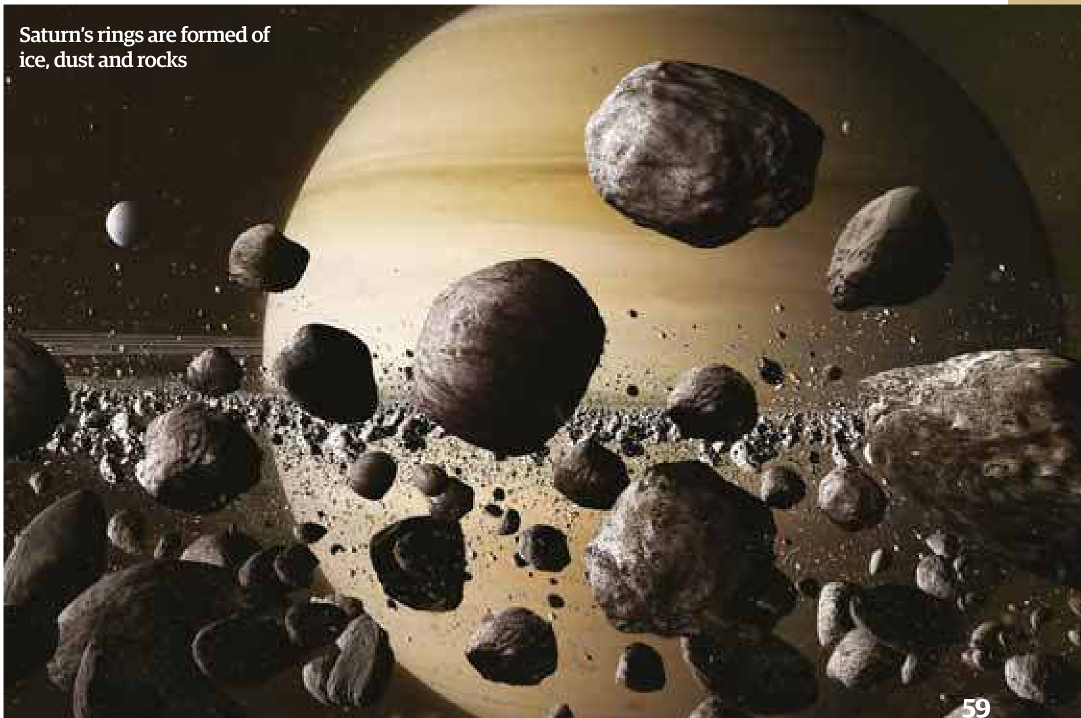
"The mass spectrometer is the spacecraft's sensitive nose," he explains. "It can determine the composition of gases with high sensitivity – we


This Cassini image focuses on the sparse, inner D ring, while the C ring, itself semi-transparent, appears below

used it to identify all the gases and ionised material [electrically charged particles] around Titan and coming out of the famous plumes on Enceladus, but especially as we flew between the rings and upper atmosphere during the Grand Finale."

The INMS, like any mass spectrometer, analyses the mass of individual gas molecules through the way they are deflected inside an electromagnetic field, but Cassini's high speed also extends its range beyond naturally gassy materials: "If we encounter a dust or ice grain at about 15 kilometres per second [9.3 miles per second] hitting our instrument antechamber, it can break apart and we'll see the volatile residue from that as well. We used that information about grains to analyse the plumes over Enceladus, and also during the Grand Finale."

For Waite and his colleagues, the most intriguing questions surrounded the composition of trace gases tenuously held in Saturn's outermost atmosphere – the exosphere – and the nature of the so-called 'ring rain' – material that slowly sifts down from the innermost D ring into the atmosphere around the equator. The existence of a 'rain' of fine water-ice particles was proposed in the early 1980s to explain certain features of Saturn's electrically charged ionosphere, and the infalling material has since been seen to leave visible traces in Saturn's


Saturn's rings are formed of ice, dust and rocks

# Saturn by the numbers

## 10,000kg

Mass of material falling onto Saturn as 'ring rain' every second.

## 22 Saturn radii

Saturn to the magnetopause, where its magnetic field is enveloped by the solar wind.

## 100kg per second

The rate at which electrically charged water ions from Enceladus are added to Saturn's magnetic plasma.

## 67-97°C

Temperature of gas in Saturn's tenuous outer atmosphere where the ring rain falls.

## 126,000 kilometres per hour

Cassini's top speed as it sped above Saturn during its Grand Finale orbits.

## 2,400 kilometres

Width of the gap between Saturn's upper atmosphere and the inner edge of the D ring.

## 294

Total number of orbits made by Cassini around Saturn.

Saturn's magnetic field is the second-most powerful of any planet in the Solar System, giving rise to spectacular northern and southern lights around its poles

> "Cassini was gone. When it got into the upper atmosphere it didn't take long to just tumble and burn up" **Dr Hunter Waite**

clouds, but Cassini's Grand Finale was the first chance to study this material in detail.

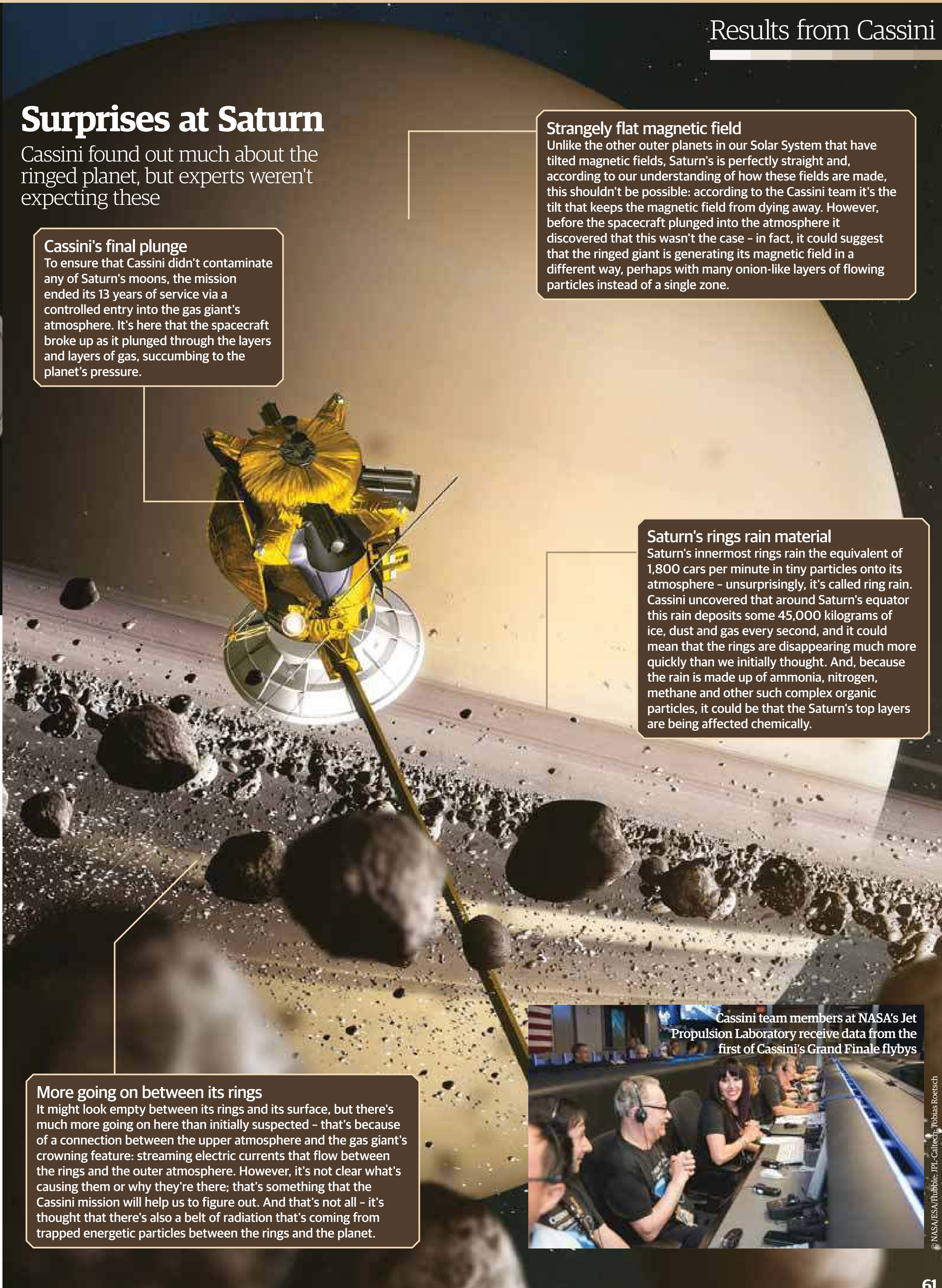
"When we saw the first spectra, at the lowest altitudes in particular, we were just startled," recalls Waite. "We'd expected to see the signatures of hydrogen and helium, and maybe a bit of water if we were lucky. But there was also methane, molecular nitrogen, carbon monoxide, carbon dioxide… There was water too, of course, but also ammonia, and all kinds of organic-compound fragments from something that broke apart in our instrument. And there was a lot of this material - if you assume it's going all the way around the planet in the equatorial region, it's something on the order of 10,000 kilograms [22,046 pounds] of material falling into the atmosphere every second."

The unexpected presence of chemically complex material close to Saturn was reminiscent of material the spacecraft found near Titan, but Waite's colleagues were able to rule out that perhaps they were simply measuring particles trapped around Titan that had later dislodged at high speeds. "One nice thing was that we had another measurement to verify at least part of what we saw," he explains. "Don Mitchell [of Johns Hopkins University] and his colleagues on the Magnetospheric Imaging Instrument used a completely independent technique to detect nanometre-scale grains of material crashing into their instrument."

Cassini's spectrometer, however, detected a mix of gases and grains. Gases including hydrogen, helium, methane, molecular nitrogen and carbon monoxide were detected alongside volatile compounds such as water, ammonia and chemically complex carbon-based 'organic' molecules released as the nanograins broke apart on impact. And since INMS sampled material it encountered along Cassini's flightpath at various locations, it can offer some direct insight into the likely origins of the different molecules. "The only material that probably originates in the atmosphere was lightweight hydrogen and helium," comments Waite. "The other material all seems to be coming from the ring system and falling into the atmosphere."

Models show that the 'rain' originates from the continuous grinding down and inward drift of material from the inner rings, so the new data suggests the ring particles themselves are either more chemically complex than the blend of simple ices previously assumed, or that they have been significantly enriched by material from comets and other chemically complex icy objects in the outer Solar System.

The large amount of material in the ring rain is also revealing, as Waite explains. "At the present rate of infall, the D ring would disappear completely in 10,000 years or so, so there has to be a process to refresh it over time. It's quite intriguing and I know



# Surprises at Saturn

Cassini found out much about the ringed planet, but experts weren't expecting these

### Cassini's final plunge

To ensure that Cassini didn't contaminate any of Saturn's moons, the mission ended its 13 years of service via a controlled entry into the gas giant's atmosphere. It's here that the spacecraft broke up as it plunged through the layers and layers of gas, succumbing to the planet's pressure.

### Strangely flat magnetic field

Unlike the other outer planets in our Solar System that have tilted magnetic fields, Saturn's is perfectly straight and, according to our understanding of how these fields are made, this shouldn't be possible: according to the Cassini team it's the tilt that keeps the magnetic field from dying away. However, before the spacecraft plunged into the atmosphere it discovered that this wasn't the case – in fact, it could suggest that the ringed giant is generating its magnetic field in a different way, perhaps with many onion-like layers of flowing particles instead of a single zone.

### Saturn's rings rain material

Saturn's innermost rings rain the equivalent of 1,800 cars per minute in tiny particles onto its atmosphere – unsurprisingly, it's called ring rain. Cassini uncovered that around Saturn's equator this rain deposits some 45,000 kilograms of ice, dust and gas every second, and it could mean that the rings are disappearing much more quickly than we initially thought. And, because the rain is made up of ammonia, nitrogen, methane and other such complex organic particles, it could be that the Saturn's top layers are being affected chemically.

### More going on between its rings

It might look empty between its rings and its surface, but there's much more going on here than initially suspected – that's because of a connection between the upper atmosphere and the gas giant's crowning feature: streaming electric currents that flow between the rings and the outer atmosphere. However, it's not clear what's causing them or why they're there; that's something that the Cassini mission will help us to figure out. And that's not all – it's thought that there's also a belt of radiation that's coming from trapped energetic particles between the rings and the planet.

Cassini team members at NASA's Jet Propulsion Laboratory receive data from the first of Cassini's Grand Finale flybys


**This pair of images show Saturn's major rings in visible light (above) and in terms of their ability to block radio signals (below). Transparency to radio signals is a useful indication of how dense the material is**

> "Most of us anticipate [the rings] will turn out to be considerably younger than Saturn" **Dr Hunter Waite**

there will be more work to come in this area on the lifetime of the rings. Most of us anticipate they'll turn out to be considerably younger than Saturn."

Meanwhile, other instruments were also gathering important information about the environment close to Saturn. While imagers captured stunning close-ups of the planet's cloud features, the long antennae of the spacecraft's magnetometer detected patterns in the planet's powerful electromagnetic field. A team led by Professor Michele Dougherty of London's Imperial College, principal investigator for the Cassini Magnetometer, has announced two surprising discoveries – confirmation that the giant planet's magnetic field is aligned to its axis of rotation with eerie precision, and a strange new magnetic effect created in Saturn's upper atmosphere.

The magnetic alignment is particularly odd and hints at new phenomena still waiting to be discovered. Because magnetic fields are created by electrically charged material swirling in somewhat chaotic currents inside a planet, they are naturally misaligned – the fields of Earth and Jupiter, for example, are tilted at around ten degrees to their axis of rotation, while those of Uranus and Neptune are not just wildly tilted, but do not even pass through the centres of their respective planets. One possibility, Dougherty suggests, is that some outside effect is 'masking' the real alignment of the field and forcing it to align with its rotation axis.

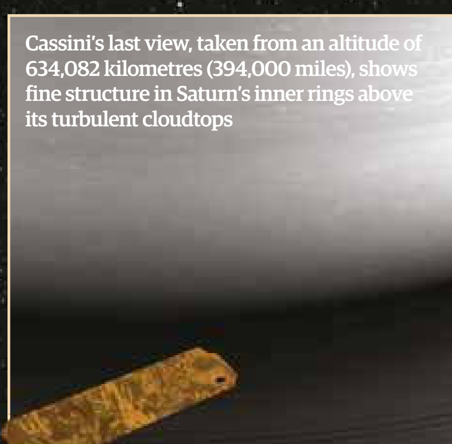
Perhaps the answer will turn out to be linked with another new magnetometer discovery – curious electric currents filling the space between Saturn and the rings. These seem to be generated as high-altitude winds flowing parallel to the equator cut through the magnetic field, but are still poorly understood. Waite hopes that the ring rain, which drifts through exactly the same region, may be able to shed some light: "We're trying to work with Michele to see if there are signatures in the material we measured and the atmospheric structure that correlate to those currents – that's an area we're actively researching right now."

Many new insights clearly still wait in the data Cassini gathered in its final days, and we can clearly expect more exciting discoveries to come. But could something as tenuous as the misty rain drifting down from the rings onto Saturn change the way we understand the origin of the Solar System itself? Waite concludes by raising this intriguing possibility.

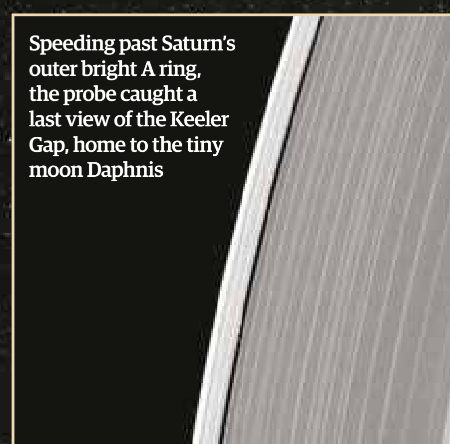
"If you dump that much methane onto the planet over the course of, say, 100 million years, you can give the upper atmosphere a veneer of carbon-bearing compounds that suggests an overall composition very different from that of the Sun," he explains. Since observation-based estimates of each planet's composition are key to understanding how the raw materials of the Solar System were distributed and where the planets formed, the possibility that Saturn's internal constituents – and potentially those of other ringed planets – are hidden, rather than reflected by their outer layers could upset previous ideas. "It's certainly made me think about what appearances are saying versus what the ultimate reality might be for this whole process of Solar System formation and evolution."

## Cassini's final photography

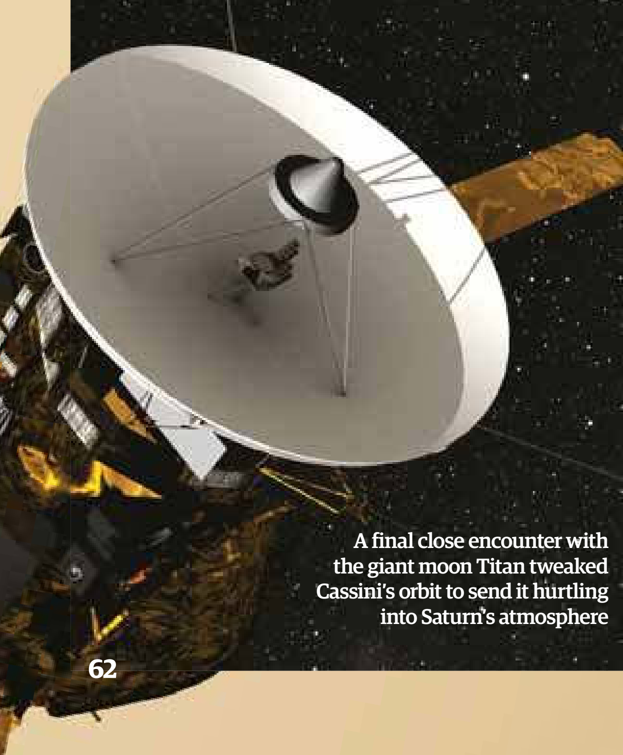
Its dive towards Saturn produced a series of spectacular images



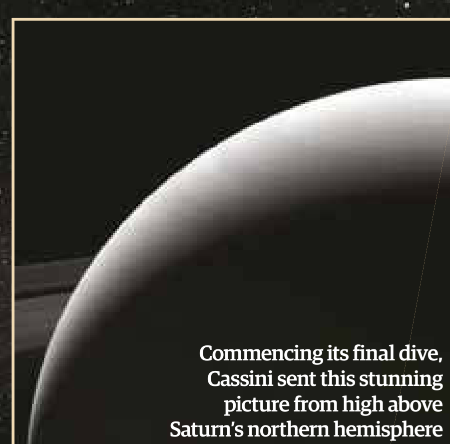
Cassini's last view, taken from an altitude of 634,082 kilometres (394,000 miles), shows fine structure in Saturn's inner rings above its turbulent cloudtops



Speeding past Saturn's outer bright A ring, the probe caught a last view of the Keeler Gap, home to the tiny moon Daphnis



A final close encounter with the giant moon Titan tweaked Cassini's orbit to send it hurtling into Saturn's atmosphere



Commencing its final dive, Cassini sent this stunning picture from high above Saturn's northern hemisphere

Planet Profile

# Jupiter

## The Solar System's planetary king is a complex world riddled with unanswered questions

The most well-known fact about Jupiter is that it is the largest planet in the Solar System - but its sheer size, which sees it stretch roughly 143,000 kilometres (89,000 miles) at the equator - doesn't even allow astronomers to scratch the surface of the gas giant's complexity. Even after much exploration of Jupiter thanks to missions from NASA and ESA, it still remains one mysterious ball of gas.

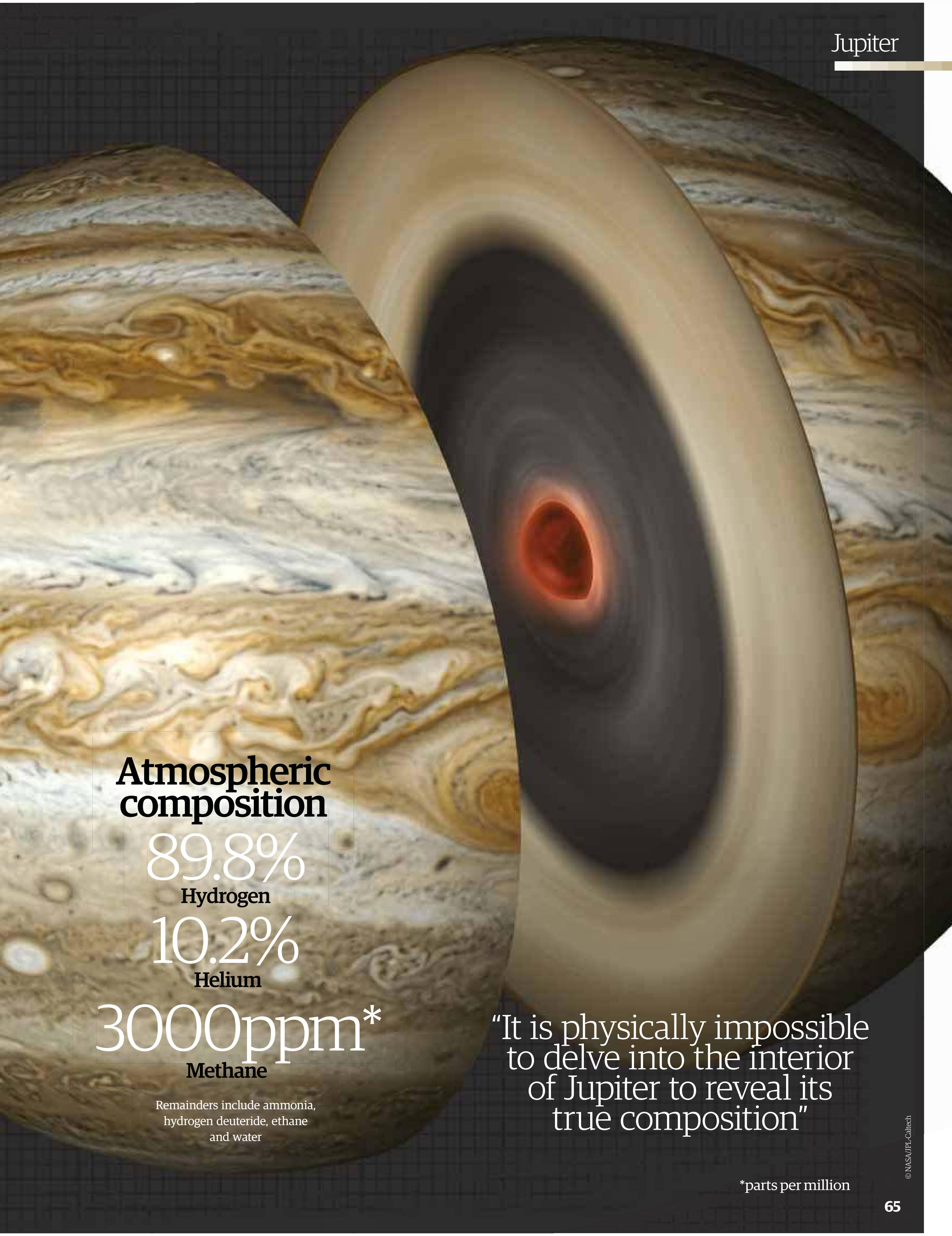
It is physically impossible to delve into the interior of Jupiter to reveal its true composition; even a carefully designed human-made spacecraft would perish in its upper atmosphere due to the enormous pressures. That's why scientists use measurements and calculations from data collected to make a well-educated guess; it's thought that Jupiter is made up mostly of the simplest and most abundant element in the universe: hydrogen. This primordial gas makes up nearly 90 per cent of the atmosphere, with 10.2 per cent being helium and the small reminder being ammonia, methane and water vapour.

The outer layer of Jupiter exhibits its famous multicoloured bands, dependant on the variety of compositions and temperatures, with strong winds carrying the layers in different directions to neighbouring features. An exceedingly obvious feature on these cloud tops is the Great Red Spot, a high-pressure anticyclonic storm, which flows in the opposite direction to the surrounding low-pressure region, that has been observed continously since 1830. The longevity of this storm has been a keen area of research for many planetary scientists aiming to understand how it has lasted so long and what precisely is powering it.

Delving deeper into the planet, it is thought that temperatures and pressures increase dramatically until the gaseous hydrogen is transformed into a liquid-metal layer. It's a process where the molecule has been stripped of its electron, which then go onto move freely through a sea of protons. This would explain why Jupiter has the most powerful magnetic field of all the planets, and this could be the driving mechanism behind a monstrous dynamo effect. At the centre of the gas giant is a solid core made up of heavier elements collected during the early stages of planetary formation.

Throughout the planet's evolution Jupiter has harvested an impressive following, with 53 named natural satellites and 26 provisional moons. Turn your telecope to the gas giant and you'll see its largest from Earth: Ganymede, Callisto, Io and Europa as points of light strung either side of its limbs. They've caught the attention of astronomers worldwide due to the exciting possibility that liquid water could reside in three of them - of course, excluding Io, which is teeming with active volcanoes.

Juno has captured remarkably close-up images of Jupiter's cloud tops



## Atmospheric composition

89.8%
Hydrogen

10.2%
Helium

3000ppm*
Methane

Remainders include ammonia, hydrogen deuteride, ethane and water

> "It is physically impossible to delve into the interior of Jupiter to reveal its true composition"

*parts per million

# Latest at Jupiter

## Jupiter is struck by lightning

When NASA's Voyager 1 spacecraft flew past Jupiter in March 1979 it observed a very peculiar phenomenon: lightning. Although it had been theorised for centuries, the radio signals produced by lightning weren't observed until this flyby. However, the lightning-associated signals didn't match the radio signals produced on Earth.

"No matter what planet you're on, lightning bolts act like radio transmitters – sending out radio waves when they flash across a sky," said Shannon Brown of NASA's Jet Propulsion Laboratory in Pasadena, California, United States, also a Juno scientist. "But, until Juno, all the lightning signals recorded by spacecraft [Voyagers 1 and 2, Galileo, Cassini] were limited to either visual detections or from the kilohertz range of the radio spectrum, despite a search for signals in the megahertz range. Many theories were offered up to explain it, but no one theory could ever get traction as the answer."

Using Juno's Microwave Radiometer Instrument (MWR), astronomers were able to deduce that a lot of activity came from Jupiter's poles, unlike on Earth where lightning tends to occur near the equator. This tells astronomers that there is not enough heating at the Jovian equator to allow warm air to rise, which is needed to produce lightning. Results like these can infer exciting new mechanisms within the atmospheres of planets beyond our own.


Juno data indicates that the majority of activity occurs near its poles

Three waves were spotted just north of Jupiter's equator

## 'Wave trains' shift across the Jovian surface

Juno has once again followed up on the observations of the Voyager missions almost 40 years ago and provided a more meticulous analysis of a strange phenomenon on Jupiter. This time the onboard JunoCam has observed massive streams of waves appearing in the atmosphere of Jupiter; these are known as 'wave trains' and can reveal a lot about the dynamics of Jupiter's atmosphere and its structure below the waves.

"JunoCam has counted more distinct wave trains than any other spacecraft mission since Voyager," said Glenn Orton, a Juno scientist from NASA's Jet Propulsion Laboratory in Pasadena, California, United States. "The trains, which consist of as few as two waves and as many as several dozen, can have a distance between crests as small as about 40 miles [65 kilometres] and as large as about 760 miles [1,223 kilometres]. The shadow of the wave structure in one image allowed us to estimate the height of one wave to be about six-miles [ten-kilometres] high."

Scientists are still analysing the data, but it's thought that the up-and-down motion of atmospheric gravity waves causes these ripples, mostly likely brought to the surface through some internal disturbance, such as a thunderstorm updraft.

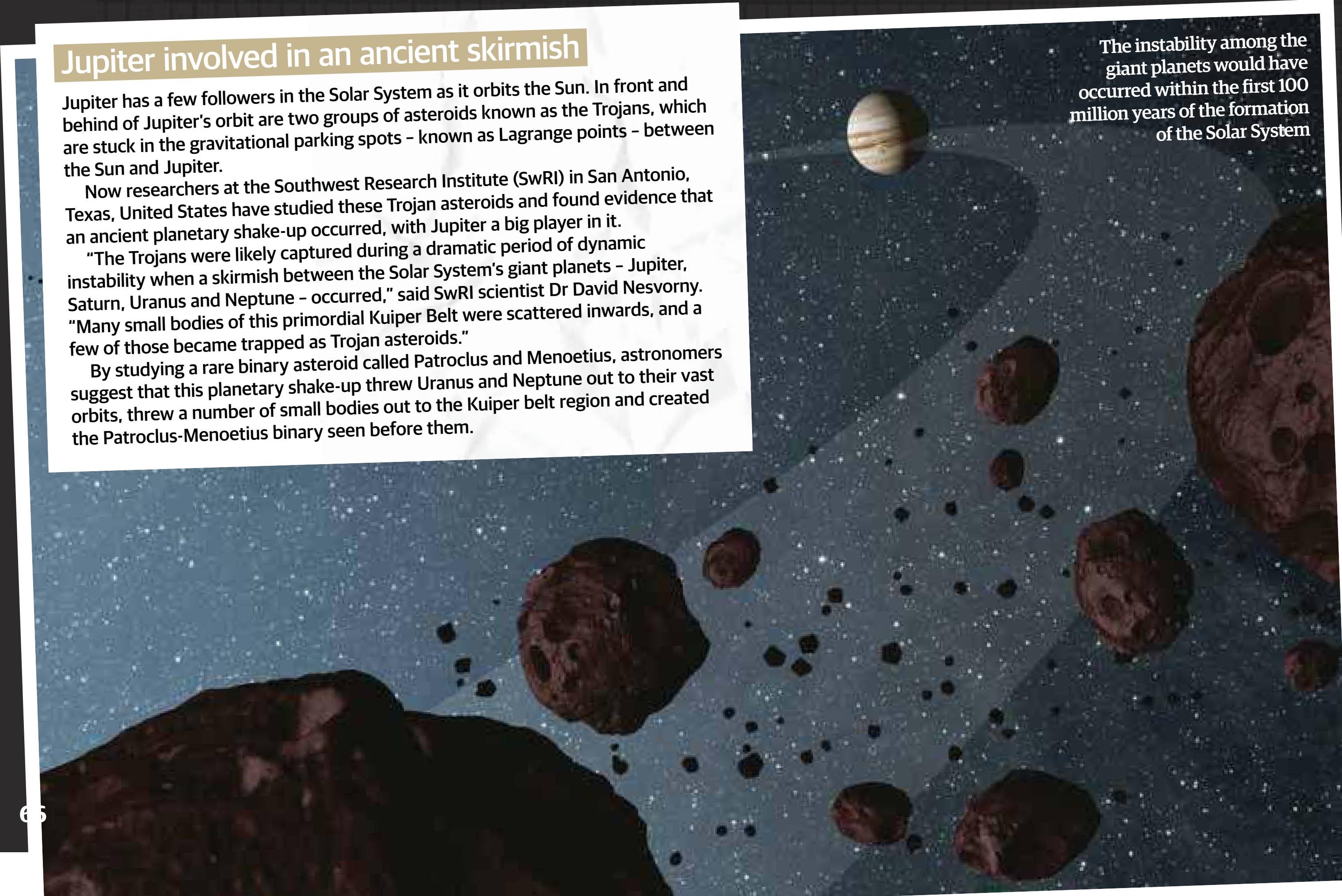
## Jupiter involved in an ancient skirmish

Jupiter has a few followers in the Solar System as it orbits the Sun. In front and behind of Jupiter's orbit are two groups of asteroids known as the Trojans, which are stuck in the gravitational parking spots – known as Lagrange points – between the Sun and Jupiter.

Now researchers at the Southwest Research Institute (SwRI) in San Antonio, Texas, United States have studied these Trojan asteroids and found evidence that an ancient planetary shake-up occurred, with Jupiter a big player in it.

"The Trojans were likely captured during a dramatic period of dynamic instability when a skirmish between the Solar System's giant planets – Jupiter, Saturn, Uranus and Neptune – occurred," said SwRI scientist Dr David Nesvorny. "Many small bodies of this primordial Kuiper Belt were scattered inwards, and a few of those became trapped as Trojan asteroids."

By studying a rare binary asteroid called Patroclus and Menoetius, astronomers suggest that this planetary shake-up threw Uranus and Neptune out to their vast orbits, threw a number of small bodies out to the Kuiper belt region and created the Patroclus-Menoetius binary seen before them.


The instability among the giant planets would have occurred within the first 100 million years of the formation of the Solar System

# Exploring a planetary king

Exploration of Jupiter has seen much progress – not as much as Earth, Mars or Venus, but it's a close fourth. If a spacecraft can make it past the asteroid belt beyond Mars, then Jupiter is there to welcome it. Jupiter has been able to act as a valuable gravitational slingshot, also known as a gravity assist, which takes advantage of its intense gravity to alter a spacecraft's speed or path.

The king of the Solar System has bestowed gravity assists to many spacecraft that aim to venture to the outer regions of our cosmic backyard, such as NASA's Pioneer 10 and 11, the two Voyager spacecraft and the New Horizons mission, as well as NASA and the European Space Agency's (ESA) Ulysses and Cassini-Huygens. The first to meet Jupiter was Pioneer 10 in 1973. It wasn't just a slingshot that Jupiter gave these missions; it also gave them a chance to test their instrumentation ahead of their destination, and these tests sent back data on the gas giant.

There have also been two main missions sent to Jupiter, however. Engineers were able to place them into orbit and gather continuous information on the mysterious workings of the Jovian king.

On 8 December 1995, NASA's Galileo spacecraft entered the orbit of Jupiter - and for nearly eight years - collected remarkable data about the planet and its moons, including observations of the Comet Shoemaker-Levy 9 collision beginning on 16 July 1994 that revealed unknown details about the planet's composition.

The second mission, still in operation, is NASA's Juno. Equipped with a finely tuned instrumental suite, Juno has been studying the interior and exterior of Jupiter since its orbital insertion on 5 July 2016.

There are plans to head back to the Jovian system in the near future, but it is to study its Galilean moons, hopefully revealing the presence of subsurface oceans. ESA's Jupiter Icy Moons Explorer (JUICE) and NASA's Europa Clipper are due to begin their journeys in June 2022 and by 2025, respectively.


Viewing Jupiter in infrared shows how energy and material are transported in the atmosphere

# Timeline of Jovian spacecraft

**Date:** 3 March 1972
**Agency:** NASA
**Spacecraft:** Pioneer 10

**Date:** 6 April 1973
**Agency:** NASA
**Spacecraft:** Pioneer 11

**Date:** 20 August 1977
**Agency:** NASA
**Spacecraft:** Voyager 2

**Date:** 5 September 1977
**Agency:** NASA
**Spacecraft:** Voyager 1

**Date:** 18 October 1989
**Agency:** NASA
**Spacecraft:** Galileo

**Date:** 6 October 1990
**Agency:** NASA/ESA
**Spacecraft:** Ulysses

**Date:** 15 October 1997
**Agency:** NASA/ESA/ASI
**Spacecraft:** Cassini-Huygens

**Date:** 19 January 2006
**Agency:** NASA
**Spacecraft:** New Horizons

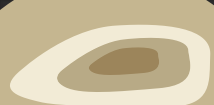
**Date:** 5 August 2011
**Agency:** NASA
**Spacecraft:** Juno

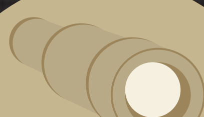
## Key

Flyby Orbiter Lander

# Jupiter's facts & stats


Jupiter's poles are home to Earth-sized storms that are closely packed together and appear to be rubbing together.

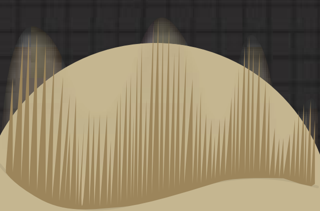

The Great Red Spot has been getting smaller over time, but it has also been getting taller. It is unclear whether this storm will continue to contract.


The Galilean moons were discovered by Italian astronomer Galileo Galilei in January 1610, and have become major targets for future exploration.

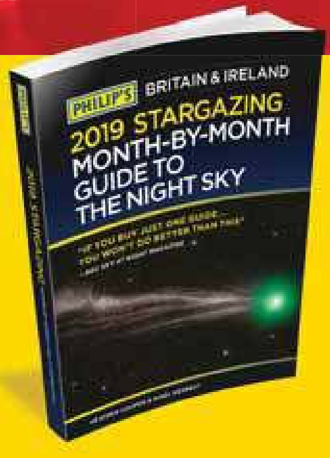
-2.94

Jupiter is the second-brightest planet in the night sky from Earth – the first being Venus – with an maximum apparent magnitude of -2.94.

Jupiter's magnetic field at its cloud tops is nearly 20-times stronger than Earth's, making it the strongest magnetosphere in the Solar System.


Aurorae – the bright lights shown at the poles of planets when electrons collide with the upper atmosphere – have been seen on Jupiter.


Jupiter has a very faint ring system consisting of an inner torus of particles, a relatively bright main ring and an outer gossamer ring.





# 2019'S HOTTEST ASTRONOMY PRODUCTS

**All About Space**'s round-up of the telescopes, books and accessories that'll enhance your views of the night sky



### Hubble Optics UL24 dobsonian

**Cost: ~£10,600 ($11,995) From: astroshop.eu**

**1** This fast Newtonian reflector is built for travel, featuring a lightweight 'sandwich' mirror that drastically reduces its weight. The UL24 weighs only 70 kilograms (154 pounds) when assembled, and breaks down into its constituent parts to fit into most vehicles. The scope's primary and secondary mirrors feature 96 per cent enhanced-reflectivity coatings, and its eyepiece stands just 77 inches from the ground when pointed at the zenith. The telescope uses eight precision-machined trusses and an optimised primary flotation system supporting the primary mirror. The telescope includes a dual-speed, 2-inch Crayford-style focuser with linear bearings engineered to support the heaviest eyepieces.

### Celestron NexYZ smartphone adapter

**Cost: ~£47 ($59.95) From: celestron.com**

**2** This unit allows you to use almost any smartphone camera to capture the brighter Solar System objects and even some deep-sky targets. Its spring-loaded clamp and innovative three-axis adjustments permit you to place your device's camera perfectly against virtually any eyepiece on a telescope, binocular or microscope quickly and precisely. Simply place your phone on the platform, centring it over the eyepiece with the X and Y knobs, and then move up or down with the Z knob over the eyepiece until you have the entire field of view in your shot. The NexYZ attaches securely to any eyepiece from 35 to 60mm in diameter with a padded clamp and adjustable safety lock. Two additional adapter rings are included for connecting the device to smaller microscope eyepieces.

### Stellarvue's Wide-Field eyepieces

**Cost: ~£270 ($349) From: stellarvue.com**

**3** Stellarvue announces an expansion of its Optimus line of 100-degree eyepieces. The new 13.5mm Optimus 1.25-inch eyepiece fills the void between 9 and 20mm offerings, adding additional versatility to the series. The ocular is sealed to prevent moisture between glass elements, and it features broadband multi-coatings on all surfaces to virtually eliminate internal reflections. The 13.5mm Optimus includes extra-durable rubber eye guards and a precision-machined 1.5-to-2-inch focuser adapter.

### Celestron 36cm Rowe-Ackermann Schmidt Astrograph

**Cost: ~£10,910 ($13,999) From: celestron.com**

**4** Celestron announces its flagship astrograph, the 36cm Rowe-Ackermann Schmidt Astrograph. This 14-inch, f/2.2 optical system is designed to record pinpoint stars across a 60mm image circle. The telescope incorporates a new moving mirror focuser design that minimises focus shift and includes ventilation fans to allow the scope to rapidly reach ambient temperature. Its 42.25-inch-long, 16-inch-diameter optical tube assembly includes two Losmandy-style mounting bars and weighs 75 pounds. Additional accessories include a 48mm camera adapter and a battery pack for the cooling fans.


## SkySafari 6

**Cost: ~£2.29 ($2.99) From: simulationcurriculum.com**

**5** One of the most popular planetarium apps for Apple devices gets a big update. SkySafari 6 once again expands the usefulness of this popular app. Among its many new functions are a 'Say It' feature that incorporates basic voice control to find and centre objects, and 'Tilt It', which uses your device's accelerometers to slew your Go To telescope. SkySafari 6 includes 29 million stars down to 15th magnitude and the PGC catalogue including 784,000 galaxies to 18th magnitude. Each of the stellar and deep-sky object catalogues is expandable with in-app purchases. Available in Basic, Plus and Pro versions, each requires iOS 8 or later. An Android version is also available.

## Tele Vue Optics bandmate filters

**Cost: ~£80 ($100) From: televue.com**

**6** Tele Vue Optics teams up with filter manufacturer Astronomik to revamp its series of nebula filters for deep-sky observing, offered in three select passbands: H-beta, OIII and the Nebustar, a unique ultra-high contrast (UHC) filter that peaks at both H-beta and OIII wavelengths. Unlike other UHC filter designs the Nebustar passband blocks redder wavelengths, producing sharper, more natural-looking stars while enhancing sought-after nebulosity. All three models are offered in 1.25-inch and 2-inch format. Each filter is manufactured in Germany by Astronomik and optically tested by Tele Vue, and includes a ten-year warranty.

## Helios Stellar-II series 100mm binoculars

**Cost: £419 (~$537) From: opticalvision.co.uk**

**7** High-quality filled observation binoculars with individual eyepiece (IF) focusing, designed for medium- to long-range terrestrial and astronomical observations. They are waterproof and nitrogen filled for fog-free operation. They incorporate a robust but lightweight magnesium-alloy body construction, covered in stylish protective black rubber armouring. Features BAK-4 prisms and a fully broadband multi-coated optical system. The optical system features high-transmission lens and prism coatings allowing 85 per cent light transmission. Eyepiece design features oversized elements, generous eye relief and fold-down rubber eyecups for spectacle wearers. Features integral tripod mounting column and central stabilising bar. Supplied in hard storage/carrying case with padded neck strap, eyepiece rainguard and objective lens caps.

## Oceanside Photo and Telescope narrowband luminance filter

**Cost: ~£293 ($375) From: optcorp.com**

**8** OPT announces a new filter for astrophotographers. The OPT Triad Tri-band narrowband filter is designed to pass wavelengths centred at 493 and 656.3 nanometers, where emission nebulae produce light, while blocking other wavelengths in the visible spectrum. This permits users to record full-colour images from light-polluted skies using DSLR and astronomical CCD or CMOS cameras. The filter is available in 1.25-inch and 2-inch formatted cells.


## FirstScope Signature Series Moon by Robert Reeves

**Cost: £59 (~$75) From: celestron.com**

**9** Celestron has joined forces with master lunar imager Robert Reeves on this new addition to the beloved FirstScope family. This quality Dobsonian-style telescope features a spherical glass mirror with a generous 76mm of aperture. The FirstScope's wide field of view provides bright, sharp views of the Moon's mountains and craters in crisp detail. You'll also enjoy using the FirstScope to pan the Milky Way, explore open star clusters, marvel at Saturn's rings or view favourite deep-sky objects like the Orion Nebula. This compact, lightweight telescope is an ideal entry-level astronomical telescope.

## Philip's 2019 Stargazing Month-by-Month Guide to the Night Sky

**Cost: £6.99 (~$9) From: Octopus Publishing Group**

**10** The new 2019 edition has been completely revised to make it even more essential for exploring the night skies, featuring 12 monthly night-sky maps, monthly calendar of Moon phases and special events in 2019, advice and best planetary viewing and much more. Essential reading for astronomers at all levels, *Philip's Stargazing Month by Month 2019* is written by two of the UK's best-known and respected astronomers. Professor Heather Couper is an internationally acclaimed astronomer, writer and presenter and Professor Nigel Henbest has been a Consultant to the Royal Greenwich Observatory.

## Meade Instruments LX65 series telescope

**Cost: ~£700 ($899) From: meade.com**

**11** The LX65 Series 6-inch MAK features a Maksutov-Cassegrain optical design for pinpoint star images and extraordinary contrast, making it a great deep-sky performer and ideal for detailed lunar and planetary observation as it easily soars to high magnifications. Features a 6-inch aperture, 1,800mm focal length and f/12 focal ratio. Equipped with an internal single-speed focuser and Ultra High Transmission Coatings (UHTC) for the improvement of brighter star clusters, more fine detail in nebulae and greater surface features on planets. Includes 26mm, 1.25-inch Plössl eyepiece and a red-dot viewfinder, along with a vixen-style dovetail.

## Meade Instruments LPI-G Advanced Camera (Monochrome)

**Cost: ~£310 ($379.99) From: meade.com**

**12** This USB 3.0 14-bit camera allows for increased dynamic range, allowing the user to experience the universe like never before! The LPI-G Advanced features a large image sensor along with a high pixel count that allows for increased resolution, making it ideal for planetary and solar imaging. Able to take 59 frames per second at full resolution, the LPI-G Advanced is able to save images in a variety of formats including JPEG, BITMAP, FITS, TIFF, PNG, PCX, TGA and BCM. It can also save videos in either SER or AVI formats. Works with Microsoft Windows XP, Windows Vista, Windows 7, 8 and 10, Mac OSX and Linux.


## Nirvana-ES UWA-82

**Cost: from £79.99 (~$100) From: opticalvision.co.uk**

**13** These top-quality ultra-wide-angle 1.25-inch eyepieces offer an incredible jaw-dropping viewing experience, but at an extremely competitive price. The huge 82-degree apparent field of view, superb field-edge correction and excellent contrast combine to provide a wonderfully immersive and memorable viewing experience. They work superbly in telescopes of all focal lengths. All models are constructed with seven lens elements in four groups. These exotic eyepiece models feature large eye-lens elements and soft fold-down rubber eyecups for comfortable viewing. All models are fully broadband multi-coated, feature blackened lens edges, internal baffling and are parfocal.

## Sky-Watcher Star Adventurer Mini WiFi (Pro)

**Cost: £279 (~$358) From: opticalvision.co.uk**

**14** A compact high-precision camera tracking platform that is ideal for long-exposure astrophotography, as well as time-lapse photography in daytime and night time settings, SAM easily fits in your backpack or camera bag, making it a convenient travel companion. SAM comes with built-in WiFi and the free Star Adventurer Mini Console App for Android and iOS platforms, allowing it to be remotely controlled with your smartphone. SAM is easy to set up and to operate in all of its modes. Although capable of supporting larger camera lenses, SAM is ideal and very simple to use for wide-field astrophotography with a standard camera lens of 55mm or shorter focal length.

## Sky-Watcher Mercury-707 (AZ-GTe)

**Cost: £329 (~$420) From: opticalvision.co.uk**

**15** The highly portable Mercury-707 has been designed to be controlled wirelessly with your smartphone or tablet using the free SynScan App. The AZ-GTe mounting, with its built-in Wi-Fi module, creates its very own Wi-Fi network so the mount can be used anywhere without relying on other Wi-Fi or mobile networks. After entering your coordinates into the App and following a simple alignment procedure, you are ready to explore the universe using the App's intuitive touchscreen menu. The AZ-GTe and SynScan App provide full computerised GO-TO control, allowing the telescope to be automatically slewed to any one of the objects in the App's database of 10,000+ objects.

## QHYCCD cooled CMOS

**Cost: ~£3,435 ($4,399) From: qhyccd.com**

**16** A 14-bit, full-frame CMOS camera for deep-sky astrophotography, the camera is designed around the Sony colour CMOS IMX094 sensor with a 7376x4938-pixel array measuring 24x36mm with 4.88-micron square pixels. The unit is capable of recording 3.2 full-resolution frames per second, and even faster rates when using on-chip region of interest. An internal 128-megabyte DDRII image buffer ensures no frames are dropped during downloads. Each camera comes with a one-metre (3.2-foot) 12V threaded power cord, a 1.5-metre (4.9-foot) USB 3.0 cable and a 2-inch nosepiece, plus a CD with camera drivers and control software.

# 33% OFF A CELESTRON TELESCOPE

## AND ACCESSORY KIT FOR EVERY READER!

Be ready for the next big comet with Celestron's special-edition Cometron FirstScope, a compact, lightweight telescope that's perfect for beginners looking to experience the magic of a dazzling comet, planet or nebula. This tabletop Dobsonian-style telescope includes a spherical mirror with a generous 76mm of aperture. The Cometron FirstScope provides bright, sharp views of comets and other celestial objects, and renders the Moon's mountains and craters in crisp detail. And, thanks to its wide field of view, you'll be able to observe the brightest part of the comet and its tail or favourite deep-sky objects like the Orion Nebula (M42).

The Cometron FirstScope offers several upgrades from the original FirstScope, including two Kellner eyepieces. The Cometron FirstScope is a tabletop telescope that you can take on all your outdoor adventures. Also featured in the package is a complimentary FirstScope Accessory Kit, featuring six separate pieces that will enhance your observations and help you to learn even more about the universe, including a Moon filter, two eyepieces of 24x and 50x magnification, a 5x24 finderscope, a soft nylon tote bag for safe storage and a bonus Starry Night Basic Edition download.


### How to claim:

To claim, simply enter AAS-COMET76 at the checkout at **dhinds.co.uk/products/celestron-cometron-firstscope-with-accessory-kit**


*Includes free accessory kit and free delivery

**Offer begins at midnight on 6 December 2018 and expires on 23:59 on 2 January 2019. Offer qualifies for a Cometron FirstScope, free accessory kit and free delivery to England, Wales and Southern Scotland. Delivery surcharge will apply to Highlands, Islands, Offshore and Northern Ireland. Stock is limited.**

# STARGAZER

ESSENTIAL GUIDES AND ADVICE FOR AMATEUR ASTRONOMERS

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**Red light friendly**
In order to preserve your night vision, you should read our observing guide under red light

# What's in the sky?

**7 DEC**
Mars and Neptune make a close approach, passing within 0°02′ in Aquarius

**7 DEC**
Conjunction between the Moon and Neptune in Aquarius

**8 DEC**
Asteroid 40 Harmonia reaches opposition in Taurus

**13 DEC**
Comet 46P/Wirtanen will make its closest approach to the Sun

**13 DEC**
The Geminids reach their peak of 100 meteors per hour

**14 DEC**
Conjunction between the Moon and Mars in Aquarius

**21 DEC**
Conjunction between Jupiter and Mercury in Ophiuchus

**21 DEC**
December Solstice in the Northern Hemisphere

**21 DEC**
The Ursids reach their peak of ten meteors per hour

**29 DEC**
Conjunction between Venus and Ceres in Libra

**29 DEC**
Asteroid 6 Hebe reaches opposition in the constellation of Monoceros

**29 DEC**
Open cluster NGC 2244 in the Rosette Nebula in Monoceros is well placed for observation

## Jargon buster

### Conjunction
A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

### Right Ascension (RA)
Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

### Declination (Dec)
This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

### Magnitude
An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

### Opposition
When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

### Greatest elongation
When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

**10 DEC**
Comet C/2018 L2 (ATLAS) is predicted to reach a brightness of about 12.7

**11 DEC**
Mercury reaches dichotomy, where it's at half phase, at magnitude -0.3 in the dawn sky

**12 DEC**
The Large Magellanic Cloud (LMC) is well placed for observation

**15 DEC**
The Moon and Mars make a close approach, passing within 3°21' of each other in Aquarius

**16 DEC**
Comet 46P/Wirtanen is predicted to reach its brightest at magnitude 6.1

**17 DEC**
Asteroid 433 Eros is at opposition at magnitude 9.4

**25 DEC**
The Moon and M44 make a close approach, passing within 0°17' of each other in Cancer

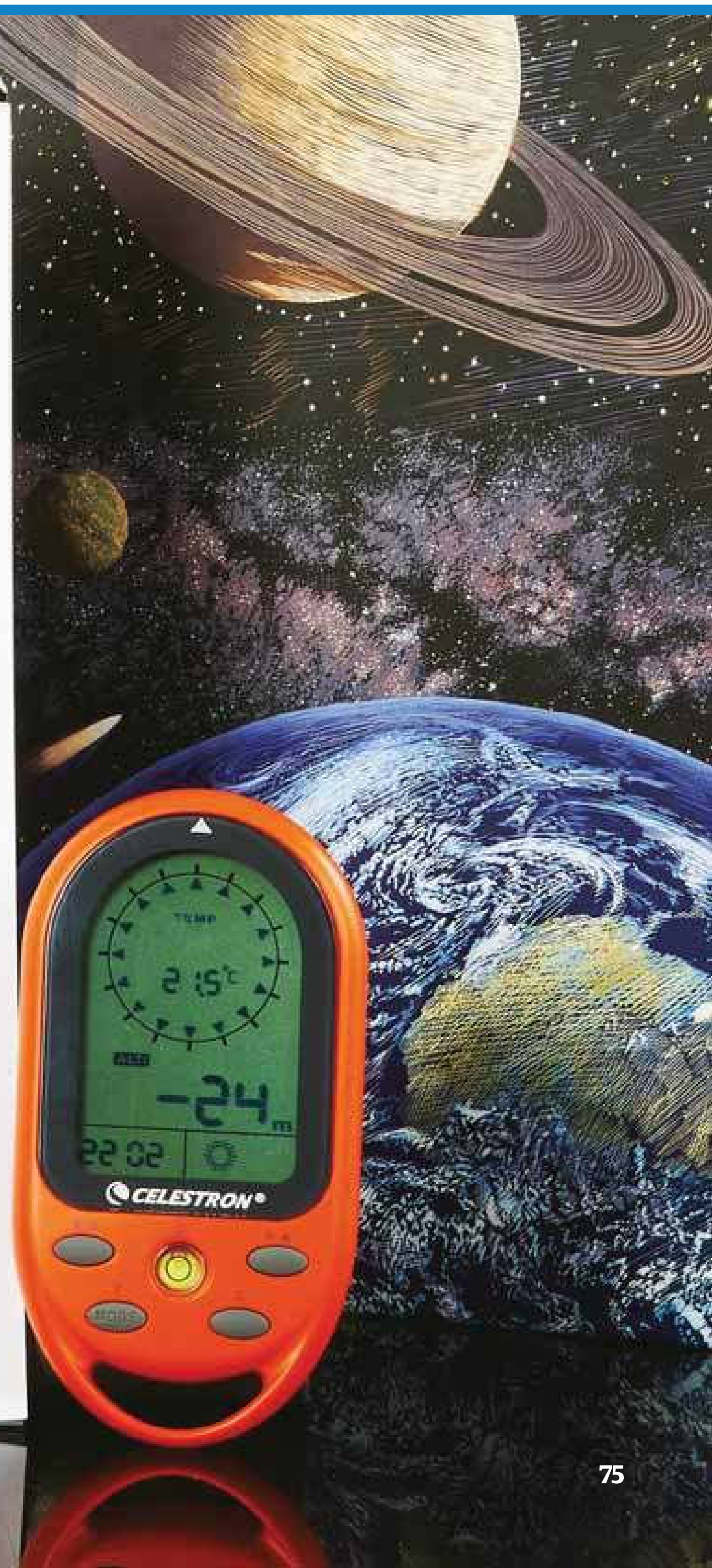
**25 DEC**
The Puppid-Velids reach their peak of 15 meteors per hour

**28 DEC**
Open cluster NGC 2232 in Monoceros is well placed for observation

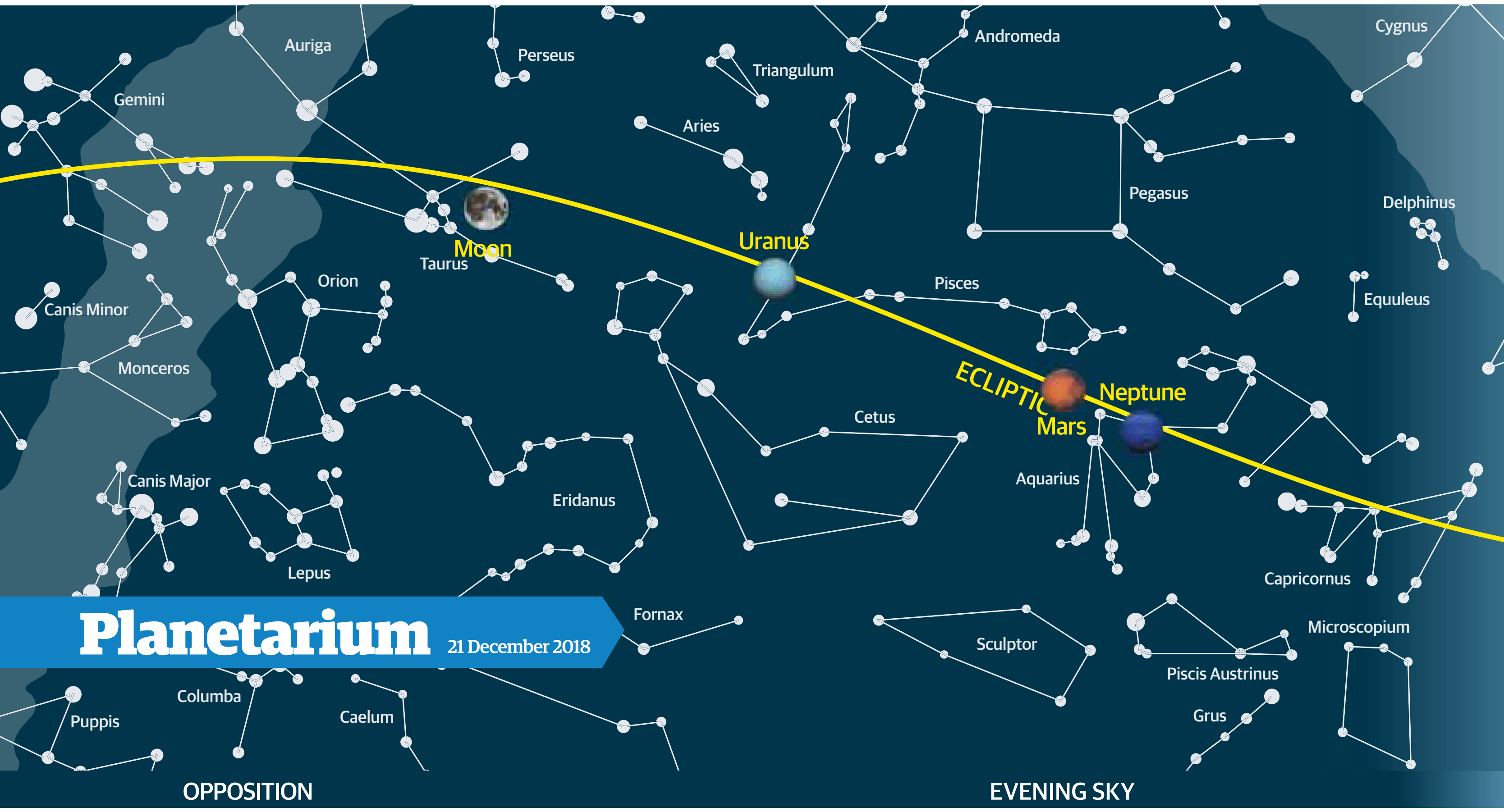
**1 JAN**
Conjunction between the Moon and Venus in Libra

**2 JAN**
Open star cluster Messier 41 is well placed for observation in Canis Major

- Naked eye
- Binoculars
- Small telescope
- Medium telescope
- Large telescope



# STARGAZER




## Planetarium

21 December 2018

OPPOSITION

EVENING SKY

## Moon calendar

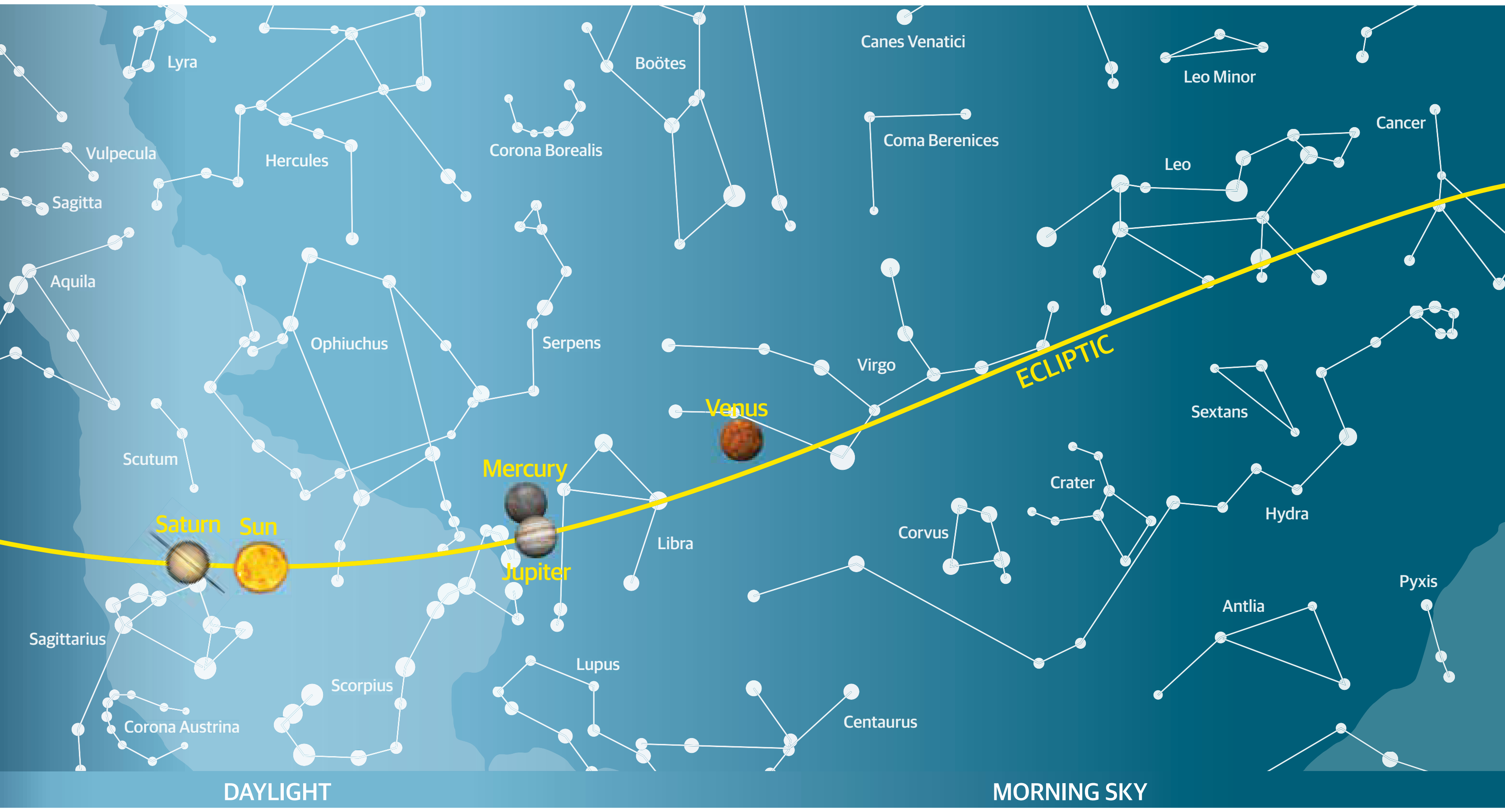
* The Moon does not pass meridian on 22 December

| Date | Phase | Illumination | Moonrise | Moonset |
|---|---|---|---|---|
| 6 DEC | | 0.9% | 06:31 | 15:47 |
| 7 DEC | NM | 0.1% | 07:38 | 16:22 |
| 8 DEC | | 1.5% | 08:40 | 17:04 |
| 9 DEC | | 5.0% | 09:35 | 17:52 |
| 10 DEC | | 10.1% | 10:21 | 18:47 |
| 11 DEC | | 16.8% | 10:59 | 19:46 |
| 12 DEC | | 24.6% | 11:31 | 20:49 |
| 13 DEC | | 33.4% | 11:58 | 21:53 |
| 14 DEC | | 42.9% | 12:21 | 22:59 |
| 15 DEC | FQ | 52.7% | 12:41 | --:-- |
| 16 DEC | | 62.7% | 13:01 | 00:05 |
| 17 DEC | | 72.5% | 13:21 | 01:13 |
| 18 DEC | | 81.5% | 13:42 | 02:23 |
| 19 DEC | | 89.4% | 14:07 | 03:36 |
| 20 DEC | | 95.4% | 14:36 | 04:52 |
| 21 DEC | | 99.1% | 15:13 | 06:09 |
| 22 DEC | FM | --.-*% | 16:00 | 07:24 |
| 23 DEC | | 99.9% | 16:59 | 08:33 |
| 24 DEC | | 97.5% | 18:09 | 09:31 |
| 25 DEC | | 92.2% | 19:28 | 10:19 |
| 26 DEC | | 84.2% | 20:48 | 10:56 |
| 27 DEC | | 74.3% | 22:09 | 11:26 |
| 28 DEC | | 63.3% | 23:27 | 11:51 |
| 29 DEC | TQ | 51.8% | --:-- | 12:14 |
| 30 DEC | | 40.5% | 00:43 | 12:36 |
| 31 DEC | | 30.0% | 01:57 | 12:58 |
| 1 JAN | | 20.6% | 03:09 | 13:22 |
| 2 JAN | | 12.8% | 04:20 | 13:50 |
| 3 JAN | | 6.7% | 05:28 | 14:22 |

% Illumination
Moonrise time
Moonset time

FM Full Moon
NM New Moon
FQ First quarter
LQ Last quarter

All figures are given for 00h at midnight (local times for London, UK)




## Illumination percentage

| | 14 DEC | 21 DEC | 28 DEC | 3 JAN |
|---|---|---|---|---|
| MERCURY | 60% | 80% | 90% | 90% |
| VENUS | 40% | 40% | 50% | 50% |
| MARS | 90% | 90% | 90% | 90% |
| JUPITER | 100% | 100% | 100% | 100% |
| SATURN | 100% | 100% | 100% | 100% |

## Planet positions

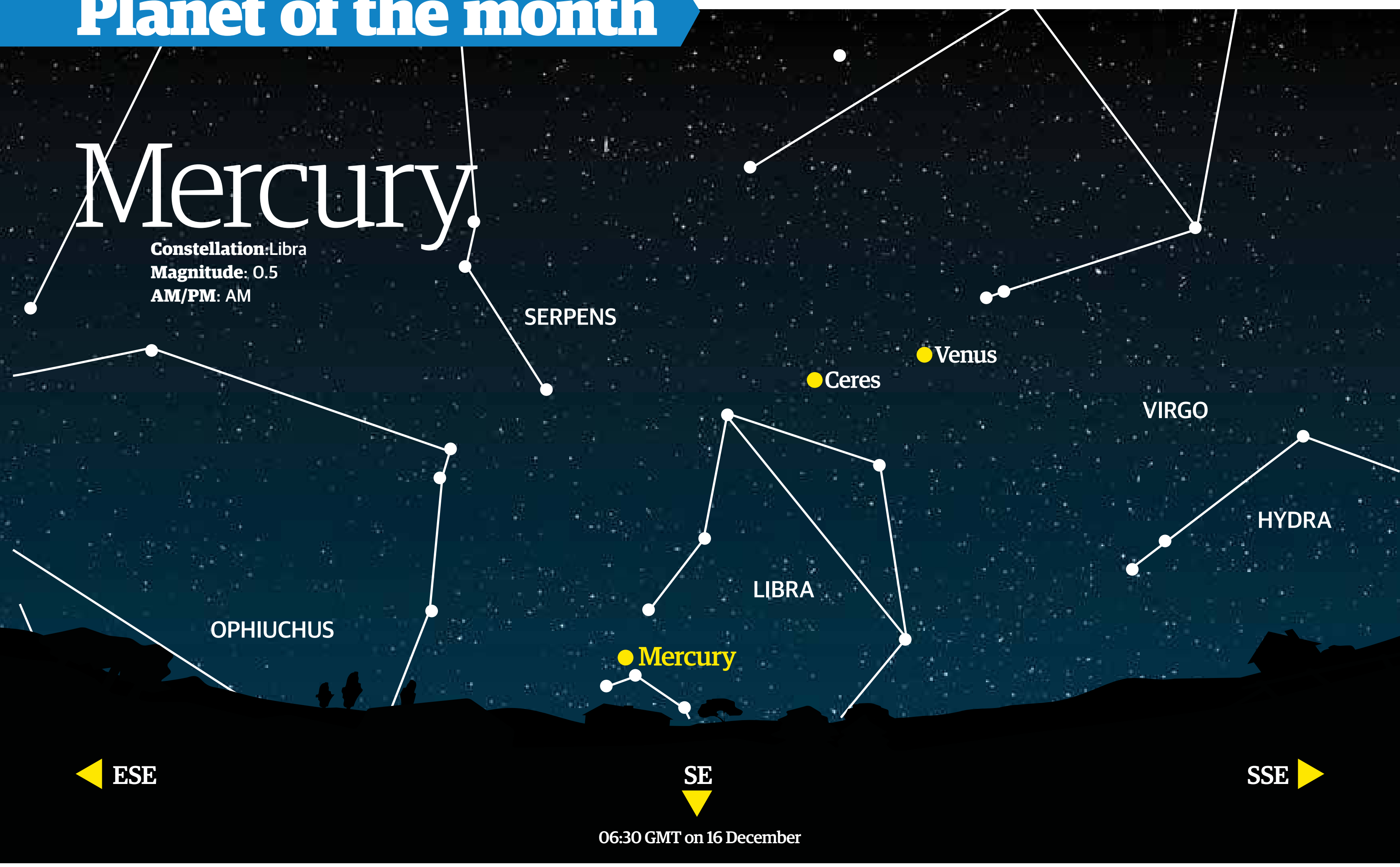
All rise and set times are given in GMT

| | Date | RA | Dec | Constellation | Mag | Rise | Set |
|---|---|---|---|---|---|---|---|
| MERCURY | 06 Dec | 15h 41m 43s | -16° 54' 40" | Libra | -0.5 | 06:07 | 15:15 |
| | 14 Dec | 15h 55m 54s | -17° 56' 08" | Libra | -0.4 | 05:56 | 14:52 |
| | 21 Dec | 16h 27m 37s | -20° 08' 59" | Ophiuchus | -0.5 | 06:13 | 14:42 |
| | 28 Dec | 17h 07m 24s | -22° 14' 37" | Ophiuchus | -0.4 | 06:39 | 14:41 |
| | 3 Jan | 17h 15m 56s | -21° 19' 35" | Ophiuchus | -0.4 | 06:17 | 14:31 |
| VENUS | 06 Dec | 14h 00m 48s | -10° 10' 20" | Virgo | -4.6 | 03:49 | 14:12 |
| | 14 Dec | 14h 23m 16s | -11° 20' 04" | Libra | -4.6 | 03:46 | 13:57 |
| | 21 Dec | 14h 46m 09s | -12° 43' 41" | Libra | -4.6 | 03:49 | 13:45 |
| | 28 Dec | 15h 11m 30s | -14° 32' 42" | Libra | -4.5 | 03:56 | 13:32 |
| | 3 Jan | 15h 30m 55s | -15° 28' 56" | Libra | -4.5 | 04:02 | 13:27 |
| MARS | 06 Dec | 22h 56m 47s | -07° 48' 23" | Aquarius | 0.1 | 12:31 | 23:19 |
| | 14 Dec | 23h 15m 52s | -05° 33' 47" | Aquarius | 0.2 | 12:07 | 23:18 |
| | 21 Dec | 23h 32m 41s | -03° 34' 01" | Aquarius | 0.3 | 11:46 | 23:17 |
| | 28 Dec | 23h 49m 35s | -01° 33' 15" | Pisces | 0.4 | 11:25 | 23:17 |
| | 3 Jan | 00h 04m 09s | +00° 10' 28" | Pisces | 0.5 | 11:07 | 23:17 |
| JUPITER | 06 Dec | 16h 16m 20s | -20° 38' 37" | Scorpius | -1.7 | 07:04 | 15:27 |
| | 14 Dec | 16h 23m 48s | -20° 56' 55" | Ophiuchus | -1.7 | 06:42 | 15:01 |
| | 21 Dec | 16h 30m 17s | -21° 11' 40" | Ophiuchus | -1.8 | 06:23 | 14:38 |
| | 28 Dec | 16h 36m 41s | -21° 25' 10" | Ophiuchus | -1.8 | 06:03 | 14:16 |
| | 3 Jan | 16h 42m 04s | -21° 35' 45" | Ophiuchus | -1.8 | 05:46 | 13:56 |
| SATURN | 06 Dec | 18h 35m 12s | -22° 40' 17" | Sagittarius | 0.5 | 09:36 | 17:32 |
| | 14 Dec | 18h 39m 06s | -22° 37' 30" | Sagittarius | 0.5 | 09:08 | 17:05 |
| | 21 Dec | 18h 42m 37s | -22° 34' 38" | Sagittarius | 0.5 | 08:44 | 16:41 |
| | 28 Dec | 18h 46m 09s | -22° 31' 23" | Sagittarius | 0.5 | 08:20 | 16:17 |
| | 3 Jan | 18h 49m 13s | -22° 28' 19" | Sagittarius | 0.5 | 07:59 | 15:57 |

# This month's planets

The swiftest planet in the Solar System returns to the dawn skies this month – make sure you're in the right place to see it

## Planet of the month




It seems like an age since Mercury watchers had anything to smile about. The closest planet to the Sun has been hard or impossible to see in the sky for months, either too close to the Sun to be seen or even hidden behind it. But finally this enigmatic, Sun-baked world is on view again, visible in the morning sky as a copper-hued star that is bright enough to be seen easily with the naked eye.

At the start of our observing period Mercury will be rising in the southeast at around 6:30am, an hour-and-a-half before the Sun. Observers with the lowest, flattest and least obstructed horizons in that direction will enjoy the best views, because Mercury's close physical proximity to the Sun means it never strays far from it in the sky, so it never climbs very far up above the horizon. If you have trees, tall buildings or hills to the southeast of your usual viewing location you might like to consider a trip to somewhere with a more favourable view if you are set on seeing little Mercury.

The best time to see Mercury will be around mid-December. Mercury will be 21 degrees from the Sun – about as far as it ever gets – and should be easy to see with the naked eye. If you don't spot it straight away, don't worry; many people, even those who consider themselves to be experienced observers, often need a little time to find it. Once you have found it – and don't worry if you need to sweep the sky with a pair of binoculars to track it down – you'll find you can go back to it easily again and again.

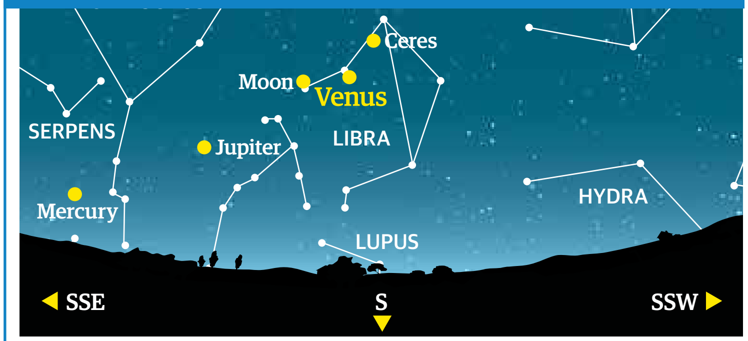
Mercury isn't alone in the sky this month – it has some very famous and regal company. Jupiter, considered by many to be the king of the planets, lies down to Mercury's lower left, very close to the horizon, while Venus, the brightest planet by far, will be blazing brightly to the upper right of Mercury.

On the mornings of 22 and 23 December Mercury and Jupiter will have a close encounter of the celestial kind where they will shine very close together in the sky. In fact, they'll be so close – just a degree, or a Moon's width, apart – that they will both fit in the same binocular field of view, and even in a telescope's low-power eyepiece's field of view too. However, the pairing will be very low in the sky, so don't be too disappointed if you don't manage to see this conjunction; you'll have other chances.

Few probes have visited Mercury, but one is en-route right now. ESA's BepiColombo probe blasted off in October. It will arrive at and begin to study Mercury in 2025, after flying past Earth and Venus along the way.

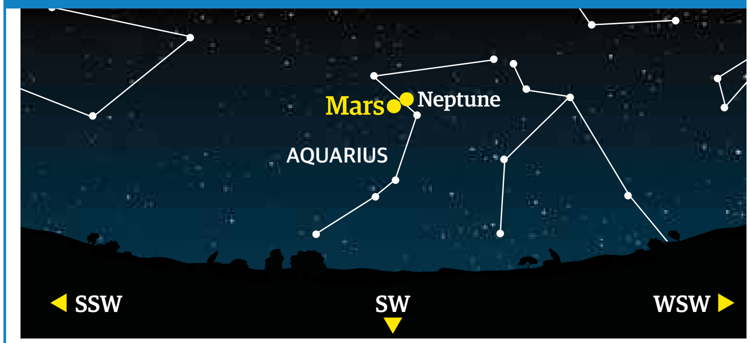
# This month's planets

## Venus 08:20 GMT on 02 January



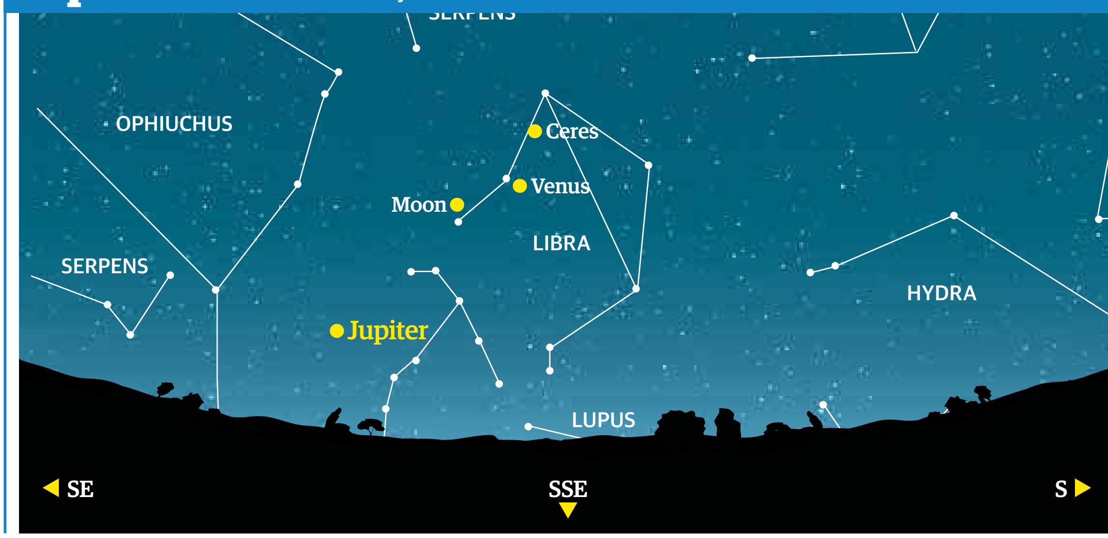

**Constellation**: Virgo
**Magnitude**: -4.6
**AM/PM**: AM
Venus really is dominating the morning sky this month. It will be at its best on 29 December when it will be 46 degrees from the Sun. Venus will also have company in the sky this month. Before sunrise on the 25th you will be able to see Venus shining to the upper right of the close pairing of Mercury and Jupiter.

## Mars 20:30 GMT on 06 December



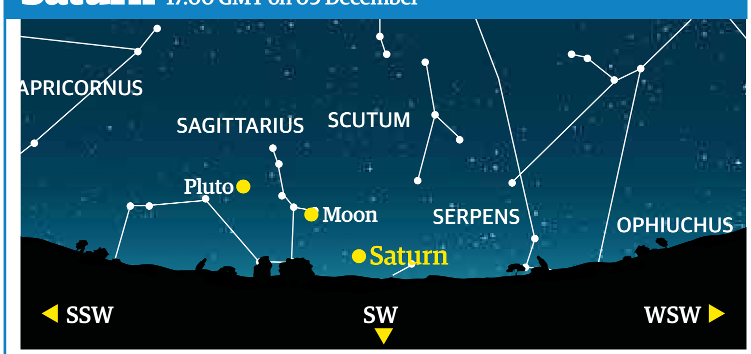

**Constellation**: Aquarius
**Magnitude**: 0.1
**AM/PM**: PM
Mars' best days for this year are definitely behind it now, but on the evening of 6 December Mars will be just half a degree from Neptune, and the next evening the pair will be just 4' apart. You'll need binoculars or a telescope to see this pairing though, as Neptune's magnitude of 7.9 means it can't be seen with the naked eye.

## Jupiter 07:00 GMT on 02 January



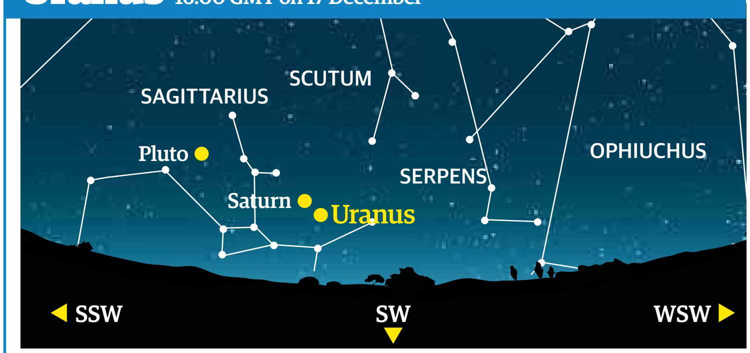

**Constellation**: Scorpius
**Magnitude**: -1.7
**AM/PM**: AM
Jupiter will be so low in the eastern sky before dawn at the start of the month that seeing it will be extremely difficult, despite its bright magnitude. By mid-December the Solar System's largest planet will be visible low in the sky close to fainter Mercury. By 21 December the two worlds will be just a degree - two Moon widths - apart. By the New Year Jupiter will be higher in the sky in Ophiuchus, much more obvious to the naked eye. Look out for a lovely waning crescent Moon shining above Jupiter and to the lower left of Venus before dawn on the morning of 2 January.

## Saturn 17:00 GMT on 09 December




**Constellation**: Sagittarius
**Magnitude**: 0.5
**AM/PM**: PM
At the start of the month Saturn will already be sinking towards the west after sunset, its summer reign well and truly over, but a good Saturn viewing opportunity will come after sunset on 9 December when the planet and a young crescent Moon will be just five degrees apart low in the southwest.

## Uranus 16:00 GMT on 17 December




**Constellation**: Aries
**Magnitude**: 5.7
**AM/PM**: PM
Uranus is visible all through the evening. Already high in the east as darkness falls, the planet has a magnitude of 5.7, meaning it is visible to the naked eye, but is best viewed through binoculars or a small telescope. Look out for the waning gibbous Moon passing beneath Uranus between 17 and 18 December.

**Top tip!**

The valley will stand out most clearly when it is near the terminator, illuminated by the Sun at a low angle.

## Moon tour

# Taurus-Littrow valley

### Visit the historic landing site of the final Apollo mission to the Moon

On 11 December 1972 - incredibly almost half a century ago - the sixth and final Apollo landing took place when the lunar module Challenger, with astronauts Harrison Schmitt and Gene Cernan onboard, set down on the surface of the Moon. It was a bittersweet occasion for thousands involved in the Apollo program and for millions of people around the world; after the incredible success of Armstrong and Aldrin's Apollo 11 mission, which saw the world holding its breath and then erupting with joy as the first boots stepped onto the dusty surface, the Apollo program had been cut short, and missions scheduled to follow Apollo 17 had been cancelled.

After reaching the Moon in triumph and exploring it with wonder and excitement, we were retreating back to Earth, called back early by politicians seeking to save money and responding to waning public support for and interest in the lunar landings. But before Gene Cernan famously became the last man on the Moon and hopped back up Challenger's ladder and closed the hatch behind him, he and geologist Schmitt spent three wonderful days on the Moon, having the time of their lives as they explored - on foot, and with the lunar rover - one of the most important and beautiful sites visited during the whole Apollo program - the Taurus Littrow valley, which is our tour destination this month.

Finding the general area of the Apollo 17 landing site is actually quite easy as it lies on the border between two of the Moon's largest and most obvious naked-eye features, namely the Sea of Serenity and the Sea of Tranquility, but you'll need a telescope to zoom in on the actual landing site itself.

If you look to the eastern 'shore' of the Sea of Serenity and follow the curve of the feature down past the well-known ringed crater Posidonius and then further down to where it meets up with the Sea of Tranquility below it, where the two meet you will find the general area of Taurus-Littrow. Another route many lunar observers take to Taurus-Littrow is to follow the raptor claw-like curve of Montes Haemus - the Haemus Mountains which form the western

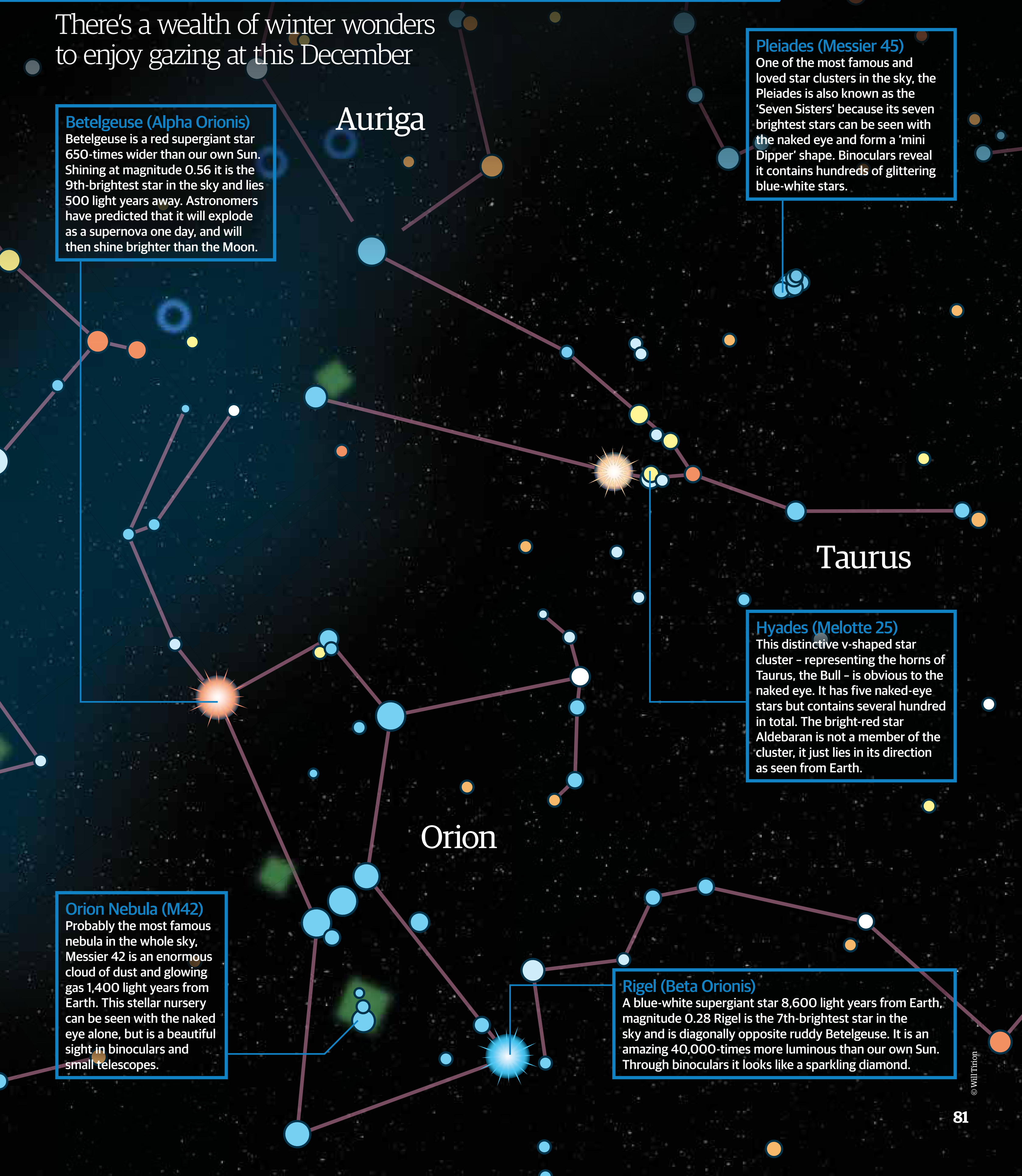
boundary between the two seas - to the crater Plinius and then hopscotch a little further east to the smaller crater Dawes. A second and final small hop to the east takes you to a much smaller mountain range, the Argaeus Mountains, and nestled within their smiley-face curve is a trio of hills. Directly between the two hills furthest from the mountains is the Taurus-Littrow Valley, where the Challenger set down 46 years ago this December.

You'll need quite a large telescope and a high-magnification eyepiece if you're going to see the actual landing site itself. You won't be able to see any of the hardware used during the mission and left behind, or the lunar rover's wheel tracks or the scuffed trails left by the Moonwalkers' boots - they are only visible from orbit through the electronic eyes of satellites - but you will be able to see some of the major features the astronauts were surrounded by as they explored the stunning lunar landscape. As for the flag they planted, their dust-covered lunar rover and their lunar module's descent stage, surrounded by crazy-paving trails of boot prints and discarded backpacks, you'll just have to imagine those...

When should you look? The landing site will not be visible until 12 December when the terminator, the line between lunar night and day, will roll over it. For the next two or three evenings the Sun will be illuminating it from a low angle so its features will really stand out. Then the valley will be illuminated from a progressively steeper angle until, by full Moon, it essentially disappears, reduced to a pattern of light and dark markings. Not until 24 December will it begin to stand out again as the terminator rolls towards it. On 27 December the valley will be swallowed up by the Stygian gloom of the lunar night once more.

# This month's naked eye targets

There's a wealth of winter wonders to enjoy gazing at this December




### Betelgeuse (Alpha Orionis)

Betelgeuse is a red supergiant star 650-times wider than our own Sun. Shining at magnitude 0.56 it is the 9th-brightest star in the sky and lies 500 light years away. Astronomers have predicted that it will explode as a supernova one day, and will then shine brighter than the Moon.

### Pleiades (Messier 45)

One of the most famous and loved star clusters in the sky, the Pleiades is also known as the 'Seven Sisters' because its seven brightest stars can be seen with the naked eye and form a 'mini Dipper' shape. Binoculars reveal it contains hundreds of glittering blue-white stars.

### Hyades (Melotte 25)

This distinctive v-shaped star cluster – representing the horns of Taurus, the Bull – is obvious to the naked eye. It has five naked-eye stars but contains several hundred in total. The bright-red star Aldebaran is not a member of the cluster, it just lies in its direction as seen from Earth.

### Orion Nebula (M42)

Probably the most famous nebula in the whole sky, Messier 42 is an enormous cloud of dust and glowing gas 1,400 light years from Earth. This stellar nursery can be seen with the naked eye alone, but is a beautiful sight in binoculars and small telescopes.

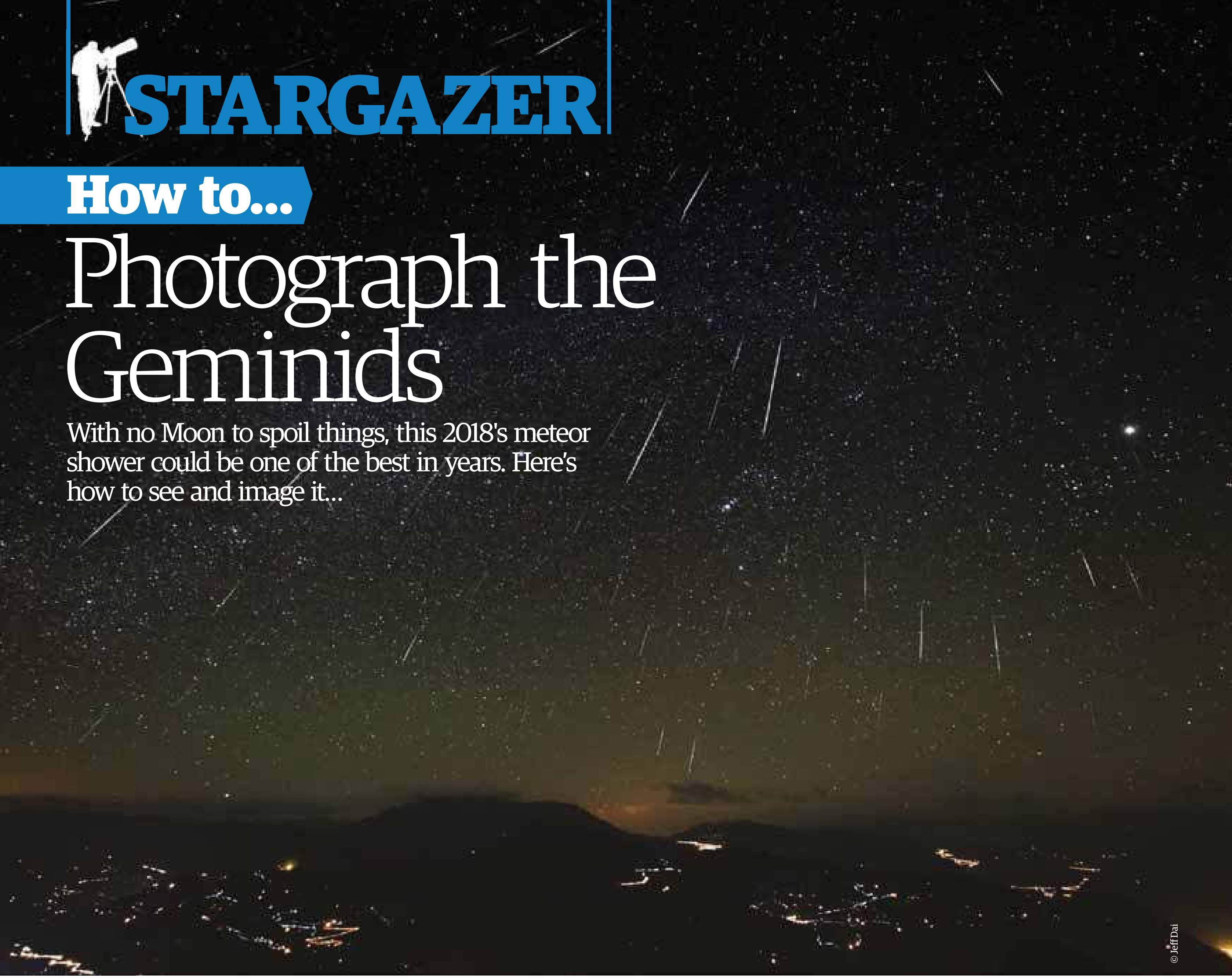
### Rigel (Beta Orionis)

A blue-white supergiant star 8,600 light years from Earth, magnitude 0.28 Rigel is the 7th-brightest star in the sky and is diagonally opposite ruddy Betelgeuse. It is an amazing 40,000-times more luminous than our own Sun. Through binoculars it looks like a sparkling diamond.

## How to...

# Photograph the Geminids

With no Moon to spoil things, this 2018's meteor shower could be one of the best in years. Here's how to see and image it...



© Jeff Dai

Every mid-December sky-watchers put aside their Christmas wrapping paper and head out into the countryside to watch shooting stars zip across the sky during the annual Geminid meteor shower. It's one of the year's most reliable meteor showers, and this year there'll be no bright Moon to spoil things so we should be in for a real treat.

This year's shower peaks on the night of 13 December, but you'll see more meteors than usual for a few nights either side of that date.

December nights can be very cold, so wear lots of layers and make sure you put on thermal socks, thick gloves and a hat too. Take a flask of a hot drink with you to warm you up when you start to feel really chilly. Taking snacks for when you need an energy boost is a good idea too.

Choosing a good observing site is absolutely vital. Find somewhere with as little light pollution and passing traffic as possible. There should also be no trees, buildings or hills to obstruct your view of the sky either. If you can find somewhere that reminds you of being in a planetarium, that's ideal.

Be at your site from 10pm and set up your camera on its sturdy tripod. Set the ISO to 800. Use a wide-angle lens, or a standard 50mm lens, but not a zoom or telephoto lens; you want your camera to capture as much of the sky as possible. Open the lens as wide as possible, and focus on a bright star or light on the horizon. Don't point your camera directly towards the radiant in Gemini. If you aim at Orion, Auriga or Ursa Major you'll have a chance of capturing a meteor with a long trail cutting through a familiar star pattern.

Using a cable release to reduce vibrations, take a test exposure of 30 seconds. Don't worry that the stars have trailed; the important thing is capturing a meteor! If everything is in focus and exposed correctly then begin taking more photos. Your camera will probably let you take ten at a time, but be prepared to fail totally: the chances of a meteor flashing across the sky exactly where your camera is pointing are very slim!

Often you'll see a bright shooting star zip across a different part of the sky to the one you're aimed at. It's then very tempting to change your target area, but try to be patient; every time you move your camera you risk losing sharp focus, though you should check focus regularly.

If you think you've caught a meteor stay patient - instead of fumbling to check with your gloved hands, check at home when you've thawed out.

> "It's one of the year's most reliable meteor showers"

## Tips & tricks

### Chase the darkness
Find an observing site with as little light pollution as possible, and a view of a large area of the sky.

### Dress for winter
December nights can be cold so dress in your warmest jacket, gloves and hat. Take a flask of a hot drink or soup – and some snacks too.

### Be patient
Be prepared for lulls in the shower. Be patient... meteors will start zipping again soon!

### Keep everything steady
Make sure your camera is mounted on a sturdy tripod and everything is tightened up. The slightest wobble will make your images blurred.

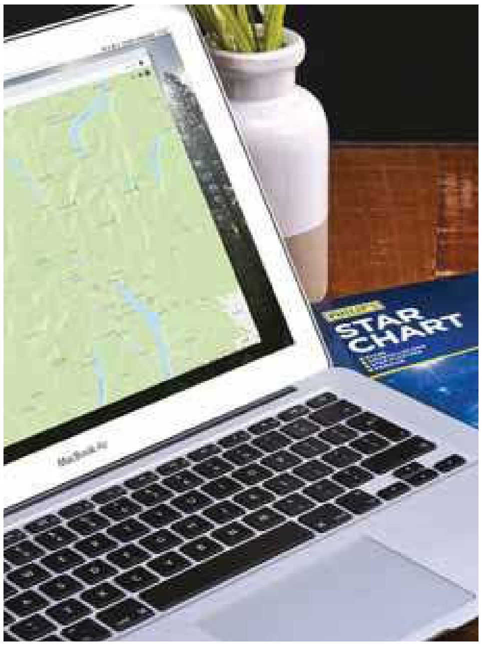
### Check your lens for dew
Check the front of your camera lens regularly. If it mists up your images will be blurred and faint.

# Getting the right settings

## How to set up your camera for your attempt at shooting the stars

Stay out as long as you can, taking as many photos as you can until you are sure you're done. Then go home and go to bed! Check your photos on your computer the next day. If you're lucky you'll have caught a few meteors with your camera, but if you haven't don't worry; seeing a bright shooting star is much more important than photographing it.

Send your photos to
**space@spaceanswers.com**




### 1 Locate an area free of light pollution

Find an observing site with no light pollution and nothing around it to block your view of the sky. The more sky you can see, the more meteors you're likely to photograph.

### 2 Wrap up warm

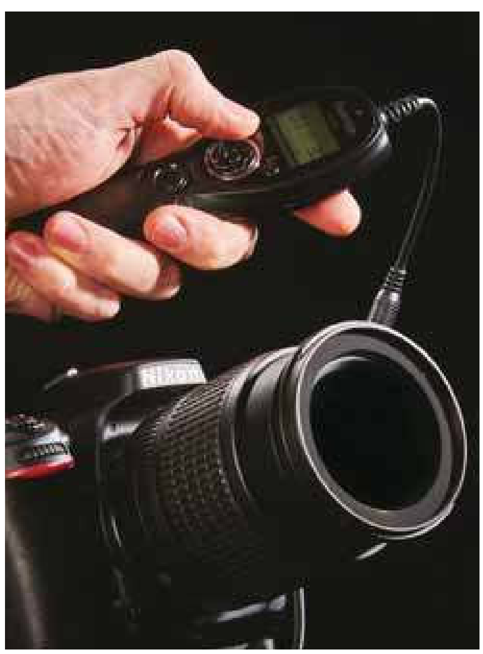
You will be outside for a long time, so dress warmly and take a flask of something hot to warm you up when it gets chilly. If you get cold you'll want to go home.


### 3 Position your camera correctly

Set up your camera with a wide-angle lens and cable release. After focusing on a bright star point it slightly away from Gemini rather than straight at it.

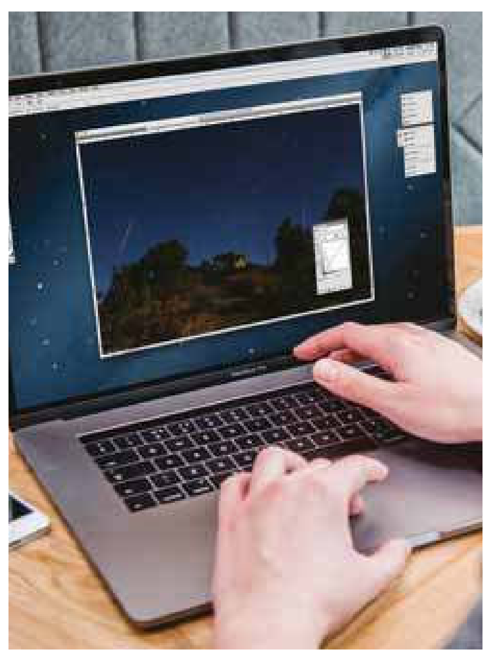

### 4 Set up an exposure of 30 seconds

Take a test exposure of 30 seconds. It's unlikely you'll catch a meteor the very first time, but you never know! If not you've got plenty more chances through the night.




### 5 Take several photos

Stay out as long as you can, taking as many photos as possible. When you feel you're done go home and straight to bed – processing your pictures can wait until the morning!





### 6 Process your shots

Go through your images on your computer. Save any that show any activity in a special folder. You should process them to bring out the colours of the meteors and the stars.

Horsehead Nebula (Barnard 33)

## Deep sky challenge

# What wonders is Orion hiding?

### The mighty Hunter has a horde of little-known treasures for you to track down and enjoy

As 2018 draws to a close nights are often sparkling clear and still, and everyone enjoys setting up their telescope on the frosty grass and gazing in awe and wonder at the green and grey billows and swirls of the Orion Nebula. But Orion has much more to offer than just that 1,400-light-years-distant stellar nursery. In and around it there are more subtle, more challenging wonders to hunt down.

This month we will help you point your telescope towards objects famous and obscure. Most observers have heard of the Horsehead Nebula, but few have seen it – we'll help you. We also have a beautiful double star, and a nebula that is as puzzling as it is pretty.

When you head out to observe the sky this month you'll find that the price of a cold, clear night is a dramatic reduction in your comfort level. You'll need to dress warmly and make sure you take regular breaks from your eyepiece to move around and get warm again. If it has snowed during the day you might find that light pollution is worse than normal as the light coming off streetlights and security lights bounces up off the snow and into the sky. Using a nebula filter or getting as far from your town or city as possible will help here.

Hubble's Variable Nebula (NGC 2261)

## 1 Hubble's Variable Nebula (NGC 2261)

At magnitude 9.19 this small, faint reflection nebula, roughly triangular or cone shaped, changes in brightness over the course of a few weeks, hence its name.

## 2 Lower's Nebula (SH 2-261)

This wispy, oval-shaped nebula is so faint and has such a low surface brightness that seeing it clearly is reserved for the owners of large or very large telescopes. Any light pollution, haze or moonlight will wash it away.

## 3 Horsehead Nebula (Barnard 33)

Essentially just a small, dark notch silhouetted against a brighter background haze, seeing it requires a large-aperture telescope, a perfect sky, averted vision and usually a nebula filter too.

## 4 The Flame Nebula (NGC 2024)

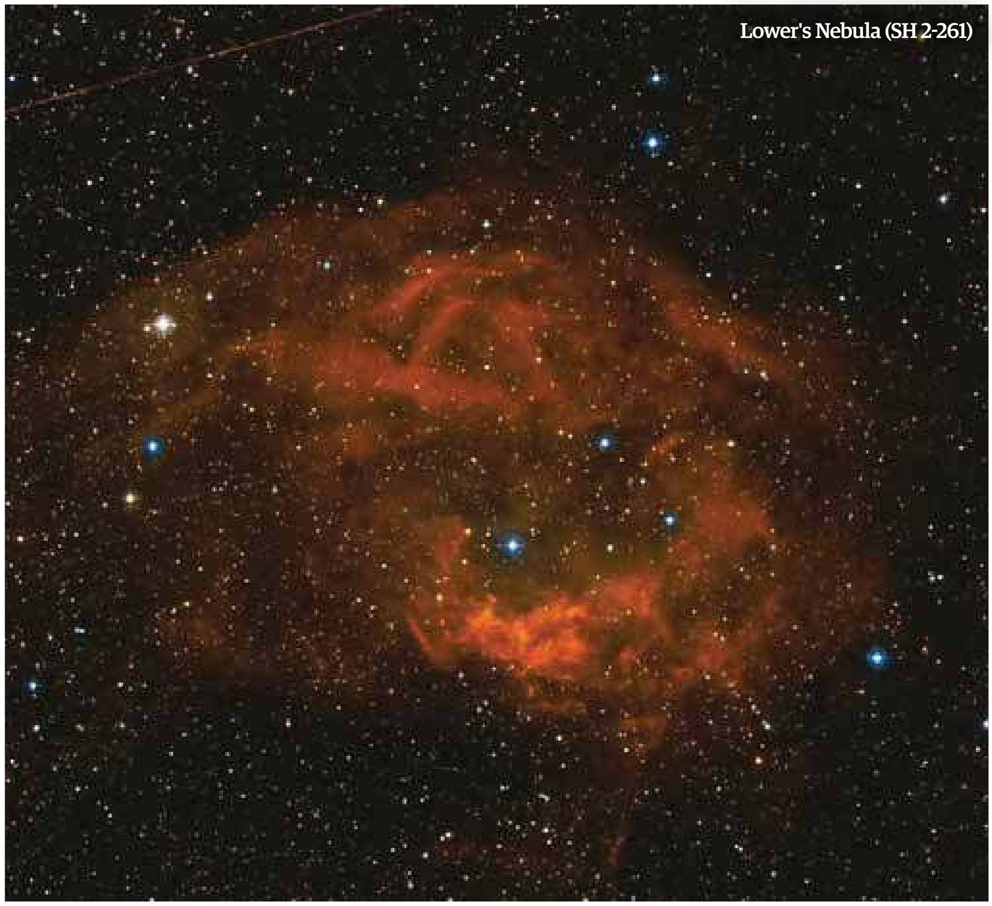
The 10th-magnitude Flame Nebula lies just to the west of bright star Alnitak. The nebula will appear as a roughly cone-shaped glow cut through with darker bands.

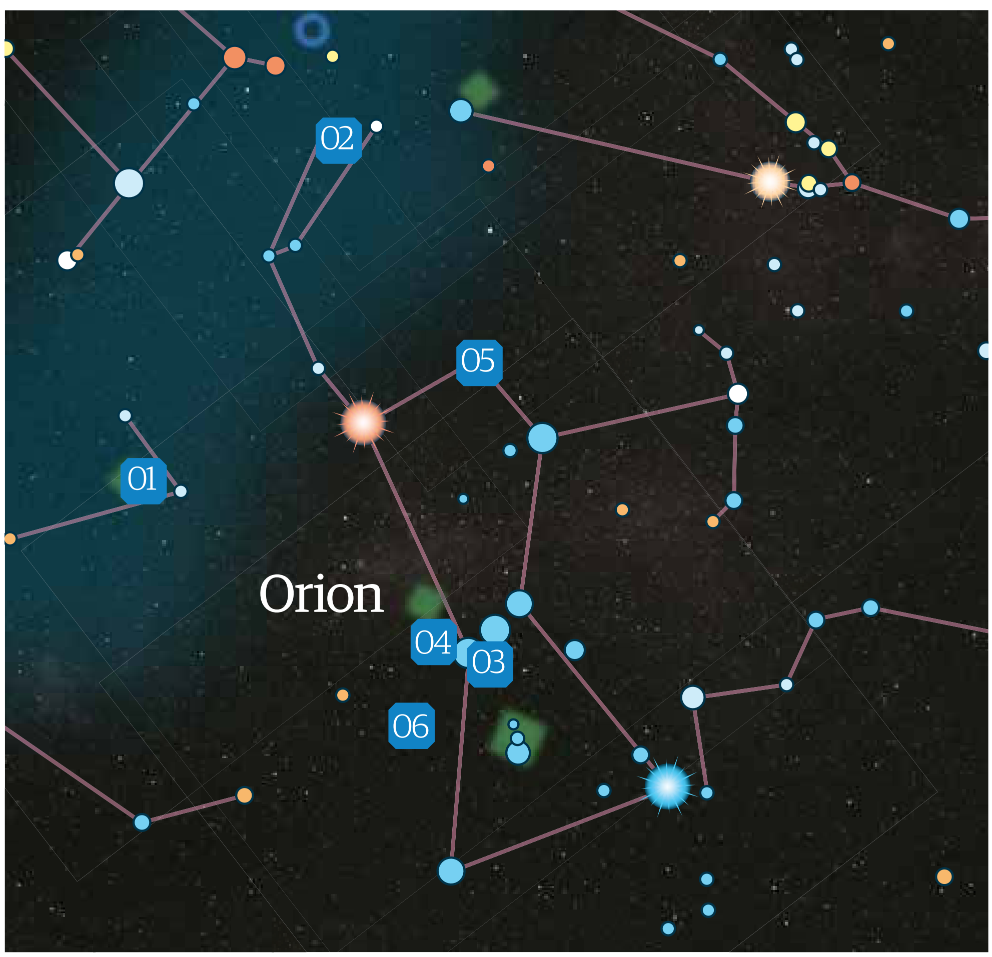
## 5 Meissa (Lambda Orionis)

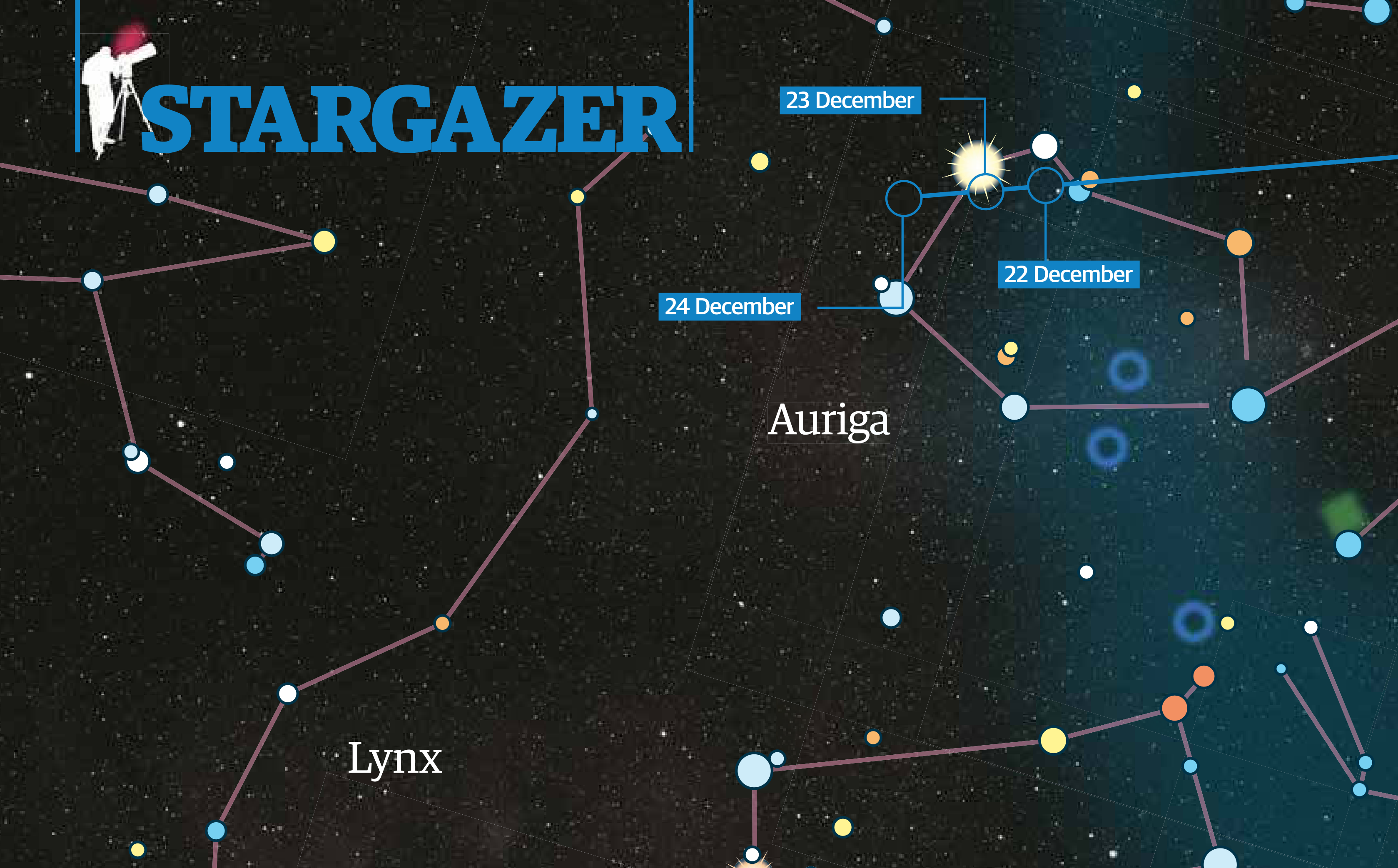
The brightest of the triangle of faint stars traditionally representing Orion's head, Meissa is a 3rd-magnitude star with a magnitude 5.6 companion. The contrast between the brighter blue star and fainter star's white colour is striking.

## 6 HD 38858

This star is worth gazing at because it is remarkable for two companions you won't see through any telescope. It is surrounded by a huge disc of comets, and is orbited by a planet twice the mass of Uranus in its habitable zone.


Lower's Nebula (SH 2-261)






**How to...**

# Track Comet 46P/Wirtanen

Fingers crossed, this month there might be a comet in the winter sky bright enough to be seen with just the naked eye

## You'll need:

- ✔ Dark-sky observing site
- ✔ Our finder charts
- ✔ Pair of binoculars (optional)
- ✔ DSLR camera on tripod (optional)

Now, no promises, but at the time of writing it looks like there might be a comet in the December sky that will be bright enough to see with the naked eye. If our predictions are accurate this comet could be visible as a small smudge to your naked eye. If not then it should still be found fairly easily with a pair of binoculars or a small telescope.

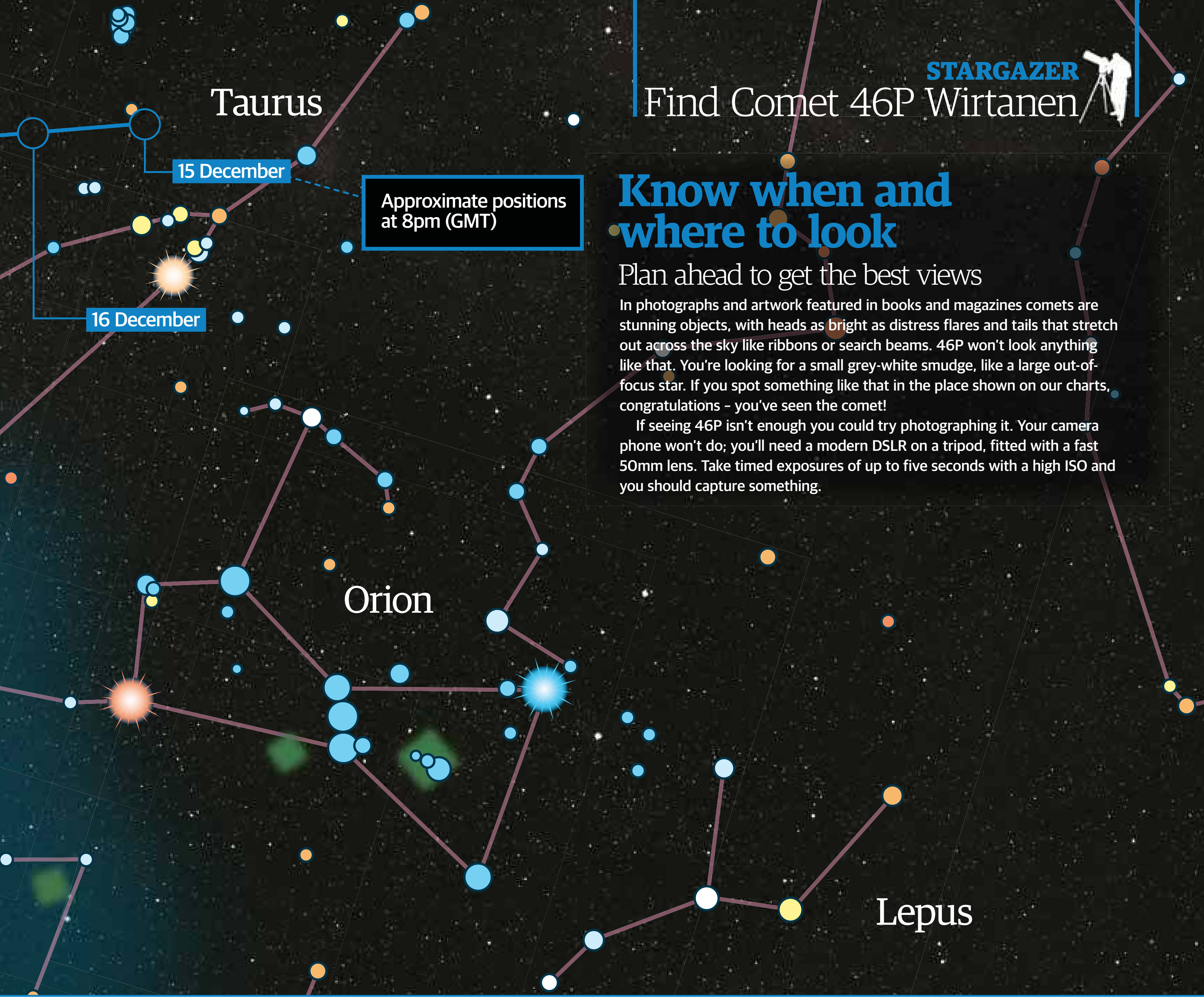
It's a long time since we had a comet in our sky that was easily visible to the naked eye, at least up in the Northern Hemisphere. While it seems like southern observers have had a naked-eye comet to ogle every few years or so, up here above the equator the last time we were able to stand in our gardens and see a comet without any help from a telescope's lenses or mirrors was in the spring of 2013 when Comet C/2011 L4 (PANSTARRS) drifted up through Andromeda and past the beautiful Andromeda galaxy, M31. Before that, Comet Holmes stunned us in November 2007 when it suddenly increased in brightness and size, for a while resembling a grey-white puffball in the sky the same size as the full Moon. But the last great comet was twin-tailed Hale-Bopp in the spring of 1996, which was so big and bright even non-astronomers could find it without any help.

Comet 46P/Wirtanen was discovered in January 1948 by astronomer Carl Wirtanen from the famous Lick observatory. It wasn't recognised as a comet for another year, but since then it has been studied intensely. We now know 46P is a chunk of dirty ice and rock around 1.2-kilometres (0.74-miles) across which orbits the Sun once every 5.4 years.

This December 46P will be coming very close to Earth, which is why it could reach naked-eye brightness. But there's no need to worry, we're perfectly safe. 'Very close' to astronomers means 'thousands if not millions of kilometres apart'. When 46P makes its closest approach to Earth on 16 December it will still be 11.5 million kilometres (7 million miles) away from us, or 30-times further away than the Moon! So, although the usual suspects will be gleefully predicting the end of the world, we're in absolutely no danger from this celestial visitor. There'll be no need for NASA to build a huge *Armageddon*-like spaceship in secret and send its crew of misfit miners and unhinged astronauts to blow 46P up. All that is going to happen is a chunk of ancient, mucky ice is going to drift silently past Earth. And, if it puts on as good a show as we're hoping, we'll have a front row seat.

Calculations based on the comet's size, activity, orbit and proximity to Earth suggest that 46P could become as bright as 3rd magnitude in mid-

> "It's a long time since we had a comet in our sky that was easily visible"




## Know when and where to look

### Plan ahead to get the best views

In photographs and artwork featured in books and magazines comets are stunning objects, with heads as bright as distress flares and tails that stretch out across the sky like ribbons or search beams. 46P won't look anything like that. You're looking for a small grey-white smudge, like a large out-of-focus star. If you spot something like that in the place shown on our charts, congratulations – you've seen the comet!

If seeing 46P isn't enough you could try photographing it. Your camera phone won't do; you'll need a modern DSLR on a tripod, fitted with a fast 50mm lens. Take timed exposures of up to five seconds with a high ISO and you should capture something.

December. If it does it will be very easy to see with the naked eye, and will look like a small smudge of chalk dust. Other calculations suggest a more modest magnitude of around 7, in which case the comet will not be visible to the naked eye, but a pair of binoculars or a small telescope will show it.

It's always best to treat such predictions with a large pinch of salt, because comets are notoriously unreliable and fickle. In the past newly discovered comets have been predicted to become 'the comet of the century', complete with tails like searchlights, only to fizzle out. We can only hope that 46P/Wirtanen behaves itself and doesn't let us down – but be prepared for it to only be visible through a telescope.

However bright it is, Comet Wirtanen will be relatively easy to track down as it will pass close to some well-known, bright objects in the winter sky: as our chart shows, 46P's path across the sky will take it up towards and then between the famous v-shaped Hyades cluster and the smaller, more obvious Pleiades or 'Seven Sisters' cluster. It will then arc towards the constellation Auriga, passing just beneath the bright-gold star Capella before dropping down towards Lynx and Ursa Major and fading away.

We have identified several nights when the comet will be particularly easy to find. On these nights you should head out to an observing site with little or no light pollution, no passing traffic and a clear view to the east and the constellations above Orion. The sky should be dark enough from 8pm to look for the comet, but once you get to your site you'll need at least half an hour for your eyes to adapt to the darkness there before you can start looking for the comet seriously.

## Tips & tricks

### Location, location, location
Find somewhere with no light pollution, a clear view to the east and no trees or buildings to block the area of sky the comet will be in.

### Be patient
Don't expect to see the comet straight away. Your eyes will have to dark adapt, and that takes at least half an hour.

### Zoom in with binoculars
If your eye can't pick out the comet take a look with binoculars. They should show it as a small, fuzzy patch.

### Look on different nights
If the weather allows you to, look for the comet on different nights so you can watch how it moves through the constellations.

### Try taking photos
If you have a DSLR camera and a tripod you can try photographing the comet. Use a 50mm lens, high ISO setting and an exposure of under five seconds.

### Enjoy the view
Don't worry about taking photos or making 'serious' observations, just enjoy looking at the comet in the sky.

Send your photos to
**space@spaceanswers.com**

# The Northern Hemisphere

The December constellations swing into view, offering an impressive array of targets to enjoy

If you're a fan of splitting double stars with your telescope then head over to the constellation of Aries (the Ram), which makes its appearance this month, bounded by the star patterns of Taurus (the Bull), Pisces (the Fishes) and Cetus (the Whale). In particular, binary star systems Lambda Arietis, Epsilon Arietis and Mesarthim are splendid targets to resolve for astronomers with medium- to large-sized telescopes. Meanwhile orange giants Hamal (the Head of the Ram) and Botein (Little Belly) can be picked out using nothing more than the naked eye.

Orion (the Hunter) is also prominent, featuring red supergiant Betelgeuse, De Mairan's Nebula (M43) and the Orion Nebula (M42).

## Using the sky chart

This chart is for use at 10pm (GMT) mid-month and is set for 52° latitude.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.


## Magnitudes

- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

## Spectral types

- O-B
- A
- F
- G
- K
- M

## Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies

**Observer's note:**
The night sky as it appears on 16 December 2018 at approximately 10pm (GMT).



Deneb (Alpha Cygni)

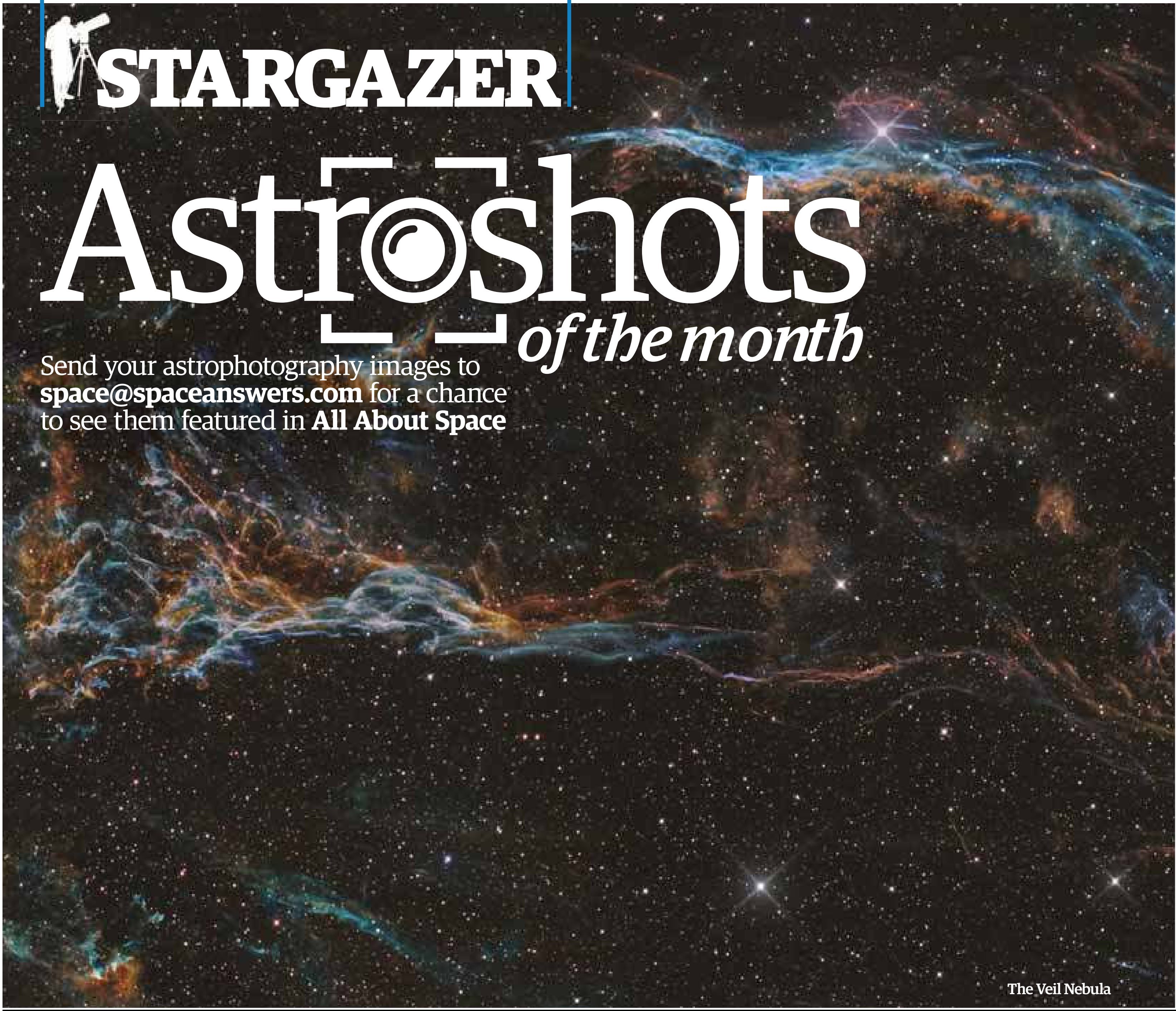

The Orion Nebula (Messier 42)


Messier 37

# STARGAZER

# Astroshots of the month

Send your astrophotography images to **space@spaceanswers.com** for a chance to see them featured in **All About Space**



The Veil Nebula

## Paul Swift

**Spain, Valencia**

"Having a good background in the arts and working professionally as a cinematographer and lighting cameraman, astrophotography made for a natural change in focus. I had always wanted to turn my camera to the skies - a move away from London to Valencia, Spain, presented me with the perfect opportunity to do just that. The combination of exploring deep space and the creative and technical art form that is astrophotography offered a powerful and alluring vocation. Any clear night I can be found setting up under darkening skies for an evening of photography and, who knows, perhaps a new discovery."

Carina Nebula (NGC 3372)

NGC 4565 and from bottom left to right Messier 13, NGC 6781 and Messier 51

## Rob Johnson

Liverpool, United Kingdom
Telescope: 14-inch Newtonian Reflector

"I have been interested in astronomy since I was seven years old, inspired by the first spaceflights and, of course, the Apollo program. Later on I became interested in photography, so it was natural to take up astrophotography.

"I enjoy imaging many kinds of targets, from deep-sky objects to Solar System bodies - I also dabble with spectroscopy. My favourite objects are galaxies and galaxy clusters; it's incredible to think of the number of planets there must be in one image, possibly harbouring life. Imaging from my light-polluted location has its challenges, but with the help of CCD cameras some great results can be achieved."

The Milky Way galaxy

## David Moug

Manitoba, Canada

Telescope: Sky-Watcher Equinox 80

"About five years ago I began my hobby in astronomy with a pair of binoculars, taking part in simple visual observing in order to learn my way around the night sky. It wasn't long until I joined a local astronomical group and, on interacting with other members, I became fascinated at how some were recording images of a variety of astronomical targets. Wanting to get involved, I started doing my own research into GoTo tracking mounts as well as auto-guiding set-ups for much more involved astrophotography."

**Send your photos to...** @spaceanswers @ space@spaceanswers.com


# Altair Astro Hypercam 183C

Built to last, this CMOS camera is ideal for those unable to decide on which facets of the universe they'd like to shoot - whether it's deep sky or the Solar System

## Telescope advice

**Cost:** £550 (approx. $704)
**From:** Altair Astro
**Type:** CMOS

## Best for...

- Beginners
- Medium budget
- Planetary imaging
- Lunar imaging
- Solar imaging
- Video astrophotography

If you're an astroimager who is always on the go then Altair Astro's IMX183 is just the CMOS for you. What's more, given its 'single colour camera' design, its 20 megapixels make it ideal for shooting both the Solar System and deep-sky targets. The camera is light, weighing in at just a third of a kilogram and requires no separate power supply. The Hypercam 183C isn't too involved when setting up - all that's required is downloading and installing a driver package before plugging in the USB 3.0 cable.

Before we could start using the Hypercam 183C in earnest, we downloaded the free AltairCapture control software to test it. The camera offers three resolutions, with a bit depth of 8 or 12 bits and, depending on the choice of target, you're either able to select the video mode to record a video file or 'trigger' mode to capture a series of individual pictures in the FITS format. We did find that switching to 12-bit mode meant that the highest resolution - found to be 5,440x3,648 - will quickly create large and unwieldy video files, but restricting the region of interest (ROI) in the image, ensures that this is avoided.

Although we disciovered that a USB 2.0 mode was more convenient for our purposes, the sacrifice in frame rate would be unacceptable if it was intended that the camera was primarily to be used for planetary, lunar or solar imaging.

Switching to USB 3.0 mode, we were able to achieve frame rates of 60 frames per second (fps) at the lowest resolution with ROI (930x688) in 8-bit mode. However, stepping up the resolution to maximum with the same ROI reduced the frame rate to a reasonable degree on the laptop we employed for this review.

We immediately took to deep-sky imaging, where we set the resolution and bit depth to maximum, turned down the gain setting before taking a series of longer exposures of a variety of objects on our Messier list. Although the pixels are a tiny 2.4x2.4 micrometres they are surprisingly sensitive, and the resulting images revealed a selection of impressive stellar colours.

It was especially pleasant to clearly see the distinction in coloration between a variety of stars that comprise late autumn's star clusters - in particular the Pleiades in Taurus, the Bull and the Beehive Cluster, also dubbed Praesepe, in Cancer. What's more, other choice targets - including the Orion Nebula (M42) - displayed stunning colour and contrast sure to delight any astrophotographer.

During our use of the CMOS we did detect some

> "The Orion Nebula (M42) displayed stunning colour and contrast sure to delight astrophotographers"

amp glow - brightening of the edges of the image. We did solve this, however, by capturing dark frames. One area this camera will excel in is the increasingly popular realm of 'electronically assisted' astronomy.

For those who struggle to observe via a traditional eyepiece, the camera can display either live images of bright targets – the Moon, Jupiter, Saturn and so on – or nearly live short exposures of fainter objects – such as galaxies, bright nebulae and comets – all visible on a computer screen. What we love in particular is there's no need to wait for your eyes to adjust to the dark; you can just observe your chosen target straight away with ease.

The rich, natural colours displayed by the stars enhanced the experience, which even seasoned astronomers will appreciate as offering an alternative and improved view to that which is available looking through eyepieces.

Jupiter too was rich in colour with a live view, with several tones of brown visible in the bands and the distinct rusty orange of the Great Red Spot clearly visible as it rotated into view.


Within the price range of a reasonable DSLR, with no need of modification for astronomy, the IMX183 offers a single-camera solution to those who primarily wish to take deep-sky photographs and also use the same camera and software for Solar System targets from time to time. The heart and soul of this camera is its CMOS sensor, the excellent Sony Exmoor R IMX183.

In-built technology allows for images with less unwanted noise and improved sensitivity. Despite the massive 20-million-pixel array the diagonal size of the sensor is just 15.86mm across, making it easier to avoid problems with distortions from coma at the edges of the image and possibly removing the requirement for a field flattener with some telescopes.

If required the sensor could easily be covered by 1.25-inch filters with no vignetting. With a possible exposure range of 0.26 milliseconds to over 16 minutes and adjustable gain, the camera is flexible enough to cater for almost every conceivable object that a telescope is able to resolve.

The gain setting offers increased sensitivity at the expense of more noise, and we were quickly able to determine optimal settings for various targets. We did enjoy the removable front filter of the camera, which allows the sensor to be cleaned if necessary - a good piece of kit for all levels of astrophotographer.


The Hypercam features a sturdy casing, while its cylindrical design helps to improve cooling

The Hypercam comes with an operating system that's only accessible through Windows


Unsure of what to image? The Hypercam allows you to have a go at shooting everything in the Solar System and deep space

# Christmas gift guide

With the holiday season just around the corner, **All About Space** selects the space gifts sure to delight any fan of the universe

## Telescope Meade Adventure Scope 80

**Cost:** £99 (~€113/$128.50) **From:** currys.co.uk

The perfect gift for lovers of the great outdoors, the adventure starts here this Christmas with the travel-ready Meade Adventure Scope 80. Functioning as both a telescope and daytime spotting scope, the generous 80mm aperture and red dot finderscope provide superior views of wildlife, landscapes, celestial objects and more, with exceptional viewing clarity and smooth tracking precision. The natural colouration of the optical tube also subtly blends in against many of natures backdrops, ideal for making discrete observations of birds and other animals. Compact in design, the Meade Adventure Scope 80 can be swiftly assembled in seconds, packing away into the accompanying lightweight backpack along with its aluminium tripod and eyepiece accessories. On camping trips, hiking, outdoor exploration or from the comfort of your own back garden, you can enjoy instant on-the-go viewing.

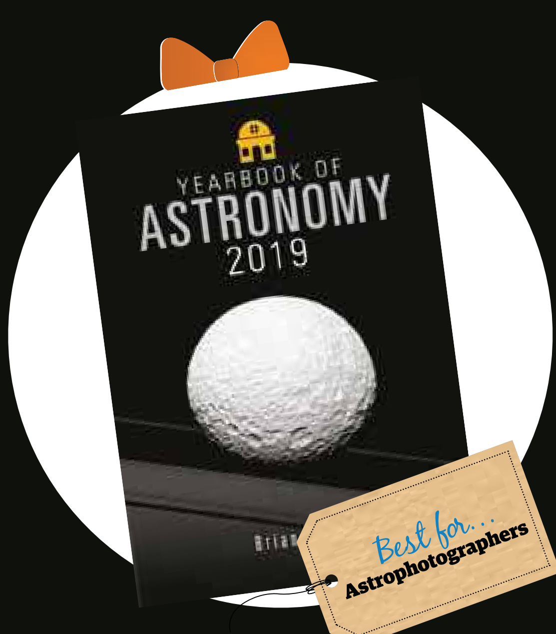
"The Meade Adventure Scope 80 can be swiftly assembled in seconds"



## Book Planetarium by Professor Raman Prinja and Chris Wormell

**Cost:** £20 (€22.80/$26) **From: Amazon**

*Planetarium* features all aspects of space, from our Solar System to the lives of stars and the Universe beyond. With stunning artwork from Chris Wormell and text by Professor Raman Prinja, *Planetarium* is the perfect gift for anyone with an interest in this fascinating field.




## Book Yearbook of Astronomy 2019

**Cost:** £16.99 (~€19.40/$22)

**From:** pen-and-sword.co.uk

An inspiration to amateur and professional astronomers alike, the *Yearbook of Astronomy* warrants a place on the bookshelf of all sky watchers and stargazers. Maintaining its appealing style and presentation, the *Yearbook of Astronomy 2019* contains an authoritative set of sky charts and comprehensive jargon-free monthly sky notes to enable backyard astronomers to plan their viewing of the year's eclipses, comets, meteor showers and deep-sky objects. The *Yearbook* has been around for well over half a century and continues to be essential reading for anyone lured by the magic of astronomy and who wants to extend their knowledge of the universe.

## Accessories
## AstroReality LUNAR PRO Globe

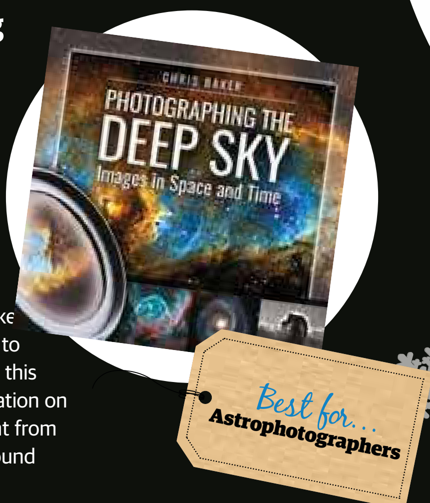
**Cost:** £222 (~€254/$288) **From:** astroshop.eu

Experience the Moon like never before! The world's first smart Moon model captures Earth's natural satellite in awe-inspiring detail and features beautiful, high-resolution topography where each feature is perfected by hand before it is finished with hand-applied colours and a safe, protective coating. Using advanced Augmented Reality technology, AstroReality Globes - paired with the AstroReality app - allow you to learn captivating facts and trivia. AstroReality weaves together an unparalleled way to experience the Moon in your hands and through your smartphone on a mission to inspire as many space lovers as possible, helping to awaken and educate a new generation of astronomy enthusiasts through the power of technology.


## Book Photographing the Deep Sky

**Cost:** £25 (~€28.50/$32.50)
**From:** pen-and-sword.co.uk

Spectacular nebulae where stars are born, beautiful star clusters from the early formation of the Milky Way and galaxies as far as a billion light years away all feature in this book of stunning images from astrophotographer Chris Baker. Depicting objects from hundreds to many millions of light years away, this book presents fascinating information on what the Earth was like when light from these objects started its Earth-bound journey through space.
Chapters are included, describing the basics of astrophotography, as modern telescopes and cameras make this a rewarding hobby well within reach of the amateur astronomer. With a concise, clear discussion on the background of astronomical science, this is a book to celebrate the beauty of the cosmos.




## Book
## 2019 Guide to the Night Sky

**Cost:** £6.99 (~€8/$9)
**From:** books.harpercollins.co.uk/astronomy

A comprehensive handbook to the planets, stars and constellations visible from the Northern Hemisphere, covering January to December 2019. This practical guide is both an easy introduction to astronomy and a useful reference for seasoned stargazers. Now includes a section on comets and a map of the Moon. It's designed for Britain and Ireland but usable anywhere in the world between 40N and 60N, covering most of Europe, southern Canada and the northern United States. Written and illustrated by astronomical experts Storm Dunlop and Wil Tirion and approved by the astronomers of the Royal Observatory Greenwich. Also available as an eBook.


## Accessories
## Omegon Mini Track LX2

**Cost:** £115 (~€131/$150) **From:** astroshop.eu

Capture the cosmos in awe-inspiring photos! The Omegon Mini Track mount is the world's first fully automatic mini-mount. No power necessary, the LX2 mount features a 60-minute tracking mechanism in a sleek and slender design. Just calibrate to the polar star, mount your camera, pull the cord and capture the cosmos in stunning photos! The Mini Track can even accompany you to anywhere in the Northern Hemisphere (Southern Hemisphere available next year). With its ability to accommodate wide-angle and telephoto lenses, it is no coincidence that this 'expert' in wide-field photography has won the hearts of amateur astronomers everywhere.


Best for…
Experience seekers

## Novelty Face in Space

**From:** faceinspace.co.uk **Cost:** £195 (~€224/$252)
Do you struggle to find a gift for someone who's got everything? The Face In Space team offers something fun and unique! They can send your special message, photo, logo or even a mince pie really high on a big weather balloon. They film it in HD video, floating with the real blackness of space with the curvature of the Earth as a backdrop. Now taking bookings for space flights departing in 2019. And that's not all – whether you want to promote your company's brand with a company logo, slogan, small item or to simply just send a photo of yourself or a friend for a special occasion, Face in Space has got it covered!

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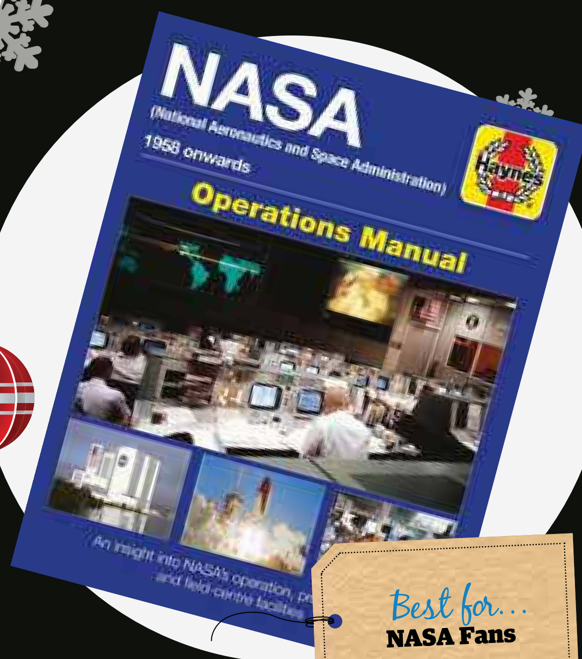


Best for…
NASA Fans

## Binoculars
## Kepler Optics GL binoculars

**From:** Optical Hardware Ltd
**Cost:** £27 (~€31/$35)
The Kepler Optics GL series are a range of traditional-style porro-prism binoculars featuring good quality BAK7 prisms combined with fully coated lenses. The GL range offer a more natural colour balance than the BR model, with a slightly brighter image.

This binocular is an exceptional-value model with a magnification suitable for most uses including birding, nature, racing, walking, plane spotting and astronomy. The rubber armouring gives a comfortable feel to the robustly constructed body. Each model in the range is tripod mountable. The 10x50 is a popular multi-purpose all-round piece of kit also well suited as an entry-level stargazing binocular. This model is sold alongside the Visionary Classic and Kepler BR so customers can compare all three and decide which is best for them.

Best for…
Amateur astronomers

## Book
## Haynes NASA Operations Manual

**From:** haynes.com/space
**Cost:** £22.99 (~€26/$30)
The Haynes *NASA Operations Manual* provides – for the first time – a comprehensive manual explaining how NASA works and operates its various programmes, opening the door to the space agency's facilities across the United States. The accessible text provides a directory of information on the various facilities, what they do, the technical parameters of their equipment and laboratory assets and how it all fits together.

Author Dr David Baker worked with NASA on the Gemini, Apollo and Shuttle programmes between 1965 and 1990 and has written more than 80 books on spaceflight technology. This book is a fascinating insight into the US agency responsible for the civilian space programme, as well as aeronautics and aerospace research.

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**A:** Jodrell Bank Observatory

**B:** Lick Observatory

**C:** Lowell Observatory

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**Congratulations to Ian Campbell, who has won a Celestron NexStar 4SE telescope**

# Akiyama Toyohiro

## How to go from journalist to Japan's first astronaut

This story has largely gone undetected in terms of space milestones, but the journey made by Akiyama Toyohiro that took him from behind a desk as a journalist to a space station around 400 kilometres (250 miles) above the Earth makes for a great story.

Born on 22 July 1942 in Tokyo, Japan, Toyohiro had no ambition to be an astronaut. He was a journalist, plain and simple. In 1966 he joined the Tokyo Broadcasting System (TBS) as a reporter, also doing some work for the British Broadcasting Corporation's (BBC) World Service in London, England. From 1984 to 1988 he worked as TBS's chief correspondent in Washington, United States, which kept him busy with the end of the Cold War drawing near.

As the 40th anniversary of TBS drew nearer plans were being made regarding how to mark such a special occasion and impressive milestone. This was when a deal was struck with the Soviet Union to use their space programme for commercial gain in sending a journalist to space. Toyohiro was the successful candidate in this crazy adventure, but first there was training to be done. Before he could take to the sky Toyohiro had to undergo numerous tests and training exercises at the Yuri Gagarin Cosmonaut Training Centre in present-day Russia.


Toyohiro conducted live reports from the Mir space station

© NASA; ITAR-TASS News Agency / Alamy Stock Photo

"Toyohiro flew on the 11th expedition to the Mir space station, titled Soyuz TM-11"

On 2 December 1990 the day had finally come for Toyohiro as he became the first Japanese person in space, surpassing his fellow countryman who were waiting to travel to space through the United States' space program. Toyohiro flew on the 11th expedition to the Mir space station, titled Soyuz TM-11, along with Soviet cosmonauts Viktor Afanasyev and Musa Manarov.

Although the cost of the deal hasn't been released, the Soviets claimed that they received £10.7 million ($14 million) and labelled it their first commercial spaceflight. For eight days on the Mir space station Toyohiro was broadcasting his experiments and experiences, making one ten-minute television broadcast and two 20-minute radio broadcasts each day.

This once-in-a-lifetime experience was brought to an end for the chain-smoking reporter for TBS aboard the Soyuz TM-10. This concluded the multi-million-pound commercial space extravaganza and put Toyohiro in the history books as not only the first Japanese astronaut, but the first 'space correspondent'.

Toyohiro left TBS in 1995 and pursued a career in organic farming in Fukushima. However, in March 2011 the farm was hit by a nuclear disaster and Toyohiro was forced to leave his farm behind. Afterwards he took up a faculty position with the Kyoto University of Art and Design in Kyoto, Japan. In an interview with *The Japan Times* he described seeing Earth from space with fascinating words: "But what still struck me as impressive was the shining blue Earth, which looked like one form of life floating in the universe," Toyohiro said. "At the same time I was reminded of the thinness of the blue layer, which is the atmosphere. So it made me visually aware that the atmosphere is so thin, and such a thin atmosphere protects every living thing – forests, trees, fish, birds, insects, human beings and everything."



All About Space

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